# DYNAMIC ASSESSMENT OF LEARNING POTENTIAL OF INDIAN ADOLESCENTS IN ALGEBRA

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# DEDICATION

This thesis is dedicated to my Dad and Mike;

two life-long learners.

# ABSTRACT

The purpose of the present study was to use an alternate psychoeducational asssessment method to examine learning potential of Indian students in an academic domain, specifically Algebra. The study examined six Indian adolescents early in their Year Seven Mathematics. For the purpose of this study, the students were classified as achievers or non-achievers based on Canadian Test of Basic Skills (CTBS) grade equivalent scores, and Grade 7 Mathematics marks on the First Report Card.

A cross-case analysis of verbal and nonverbal protocol data gathered from the six Indian achieving and non-achieving Grade Seven students, and reduced through use of a technique developed by Giorgi, yielded information regarding the subjects' internalization processes of algebraic concepts. Vygotsky's zone of proximal development methodology, which was employed in the study, permitted the researcher to investigate processes used by the students during learning, maintenance, and near and far transfer tasks. While verbal and nonverbal communication styles appeared to distinguish achieving from non-achieving students, those same traits did not seem to affect efficiency in problem solving as observed during the present study. Other characteristics such as language usage, questioning techniques, and risk taking were the traits which most clearly affected the students' problem solving skills.

During the present study, formal metacognitive data proved hard to collect. This may be attributed to the reluctance of some students to participate in the questioning, and to the difficulty other students experienced in understanding the questions. All students had difficulty at some stage of the study in generating a rule to explain how they had solved the problems.

The results of the present study indicated that there were qualitative differences in problem solving between subjects. Those qualitative differences did not follow a pattern of achievement versus non-achievement as delineated by CTBS scores and classroom evaluation in Mathematics. Zone proximal development methodology provided a process assessment which uncovered learning potential profiles that were masked by static standardized tests.

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Suppose I investigate two children upon entrance into school, both of whom are ten years old chronologically and eight years old in terms of mental development. Can I say that they are the same age mentally? Of course. What does this mean? It means that they can independently deal with tasks up to the degree of difficulty that has been standardized for the eight-year-old level. If I stop at this point, people would imagine that the subsequent course of mental development and of school learning for these children will be the same, because it depends on their intellect. . . . . Now imagine that I do not terminate my study at this point, but only begin it. These children seem to be capable of handling problems up to an eight-year-old's level, but not beyond that. Suppose that I show them various ways of dealing with the problem. Different experimenters might employ different modes of demonstration in different cases: some might run through an entire demonstration and ask the children to repeat it, others might initiate the solution and ask the child to finish it, or offer leading questions. In short, in some way or another I propose that the children solve the problem with my assistance. Under these circumstances it turns out that the first child can deal with problems up to a twelve-year-old's level, the second up to a nine-year-old's. Now are these children mentally the same? (Vygotsky, 1978, p. 85-86).

# CHAPTER ONE

## 1.1 BACKGROUND

Statistics show that more than 70 percent of Native students in the province of Saskatchewan do not complete high school (Saskatchewan Education, 1984 & 1985; Struthers, 1989). Socio-economic and cultural circumstances, language and learning styles, lack of appropriate curriculum, community non-participation, teacher expectations, and poor self-concept have been considered causes for early school withdrawal (Benjamin, 1987; Bowd, 1982; Bradley, 1984; Parnell,1976; Rampaul, Singh & Didyk, 1984). Initiatives undertaken to improve the dropout situation have included establishing Band control of education, developing more pertinent curriculum, and setting up alternative high schools. The problem has also been addressed by Native teacher education, social work, and vocational programs (Saskatchewan Education, 1984).

Research in Native education has focused on effectiveness of teachers (Kleinfield, McDiarmid, Grubis, & Parret, 1985), inter-ethnic communication (Scollon & Scollon, 1981), Standard English as a second dialect (Connelly, 1985), self-concept (Barner & Vulcano, 1982; Parry, 1982), nonverbal communication (Greenbaum, 1985; Greenbaum & Greeenbaum, 1983; Philips, 1972), achievement in schools (McShane, 1985), and intellectual functioning (Krywaniuk & Das, 1976; McShane & Plas, 1984a).

The qualitative research approach in psychoeducational assessment has been neglected in Native education. Most studies in assessment follow the quantitative research paradigm and use psychometric tests of intelligence to compare Native people with a representational sample of the general population (Osbourne, 1985). Psychometric tests have been criticized for misdiagnosing learning potential in culturally different students (Campione, Brown & Ferrara, 1984; Cole & Bruner, 1979; Cummins, 1986; Seyfort, Spreen, & Lahmer, 1980). Low test scores may result in the establishment of a "compensatory education" program based on the underlying assumption that the deficit responsible for the low score is within the child (Bernstein, 1972; Cummins, 1986; Labov, 1972).

This assumption often does not acknowledge that a low test score may result from a mismatch between the mainstream culture and the culturally different child, whose life experiences may result in different ways of understanding the world. This variant experiential base could, in turn, affect the type of knowledge or language she or he has acquired (Cole & Bruner, 1979; Donaldson, 1978). While the use of these tests with members of minority cultures has long been suspected of cultural bias (Cummins, 1986), the practice of comparing Native children to norms based on the mainstream culture continues.

Intelligence tests are not the only type of standardized procedures in psychoeducational assessment that compare native populations to normative data from the prevalent culture. Achievement tests examine a variety of skills; normative tables

compare the performance of an individual child against the scores of many others. Such tests are used widely, particularly in the academic areas of Language and Mathematics. The Canadian Test of Basic Skills (CTBS) is an example of such a test.

In many Saskatchewan schools, decisions to separate students into Grade Ten Algebra and General Mathemetics are based on students' CTBS scores, students' past performances in Mathematics, and teachers' referrals. This practice may contribute to limited enrollment of Native people in Algebra courses.

Research in cognition and mathematics suggests that there is a cultural influence in the development of mathematical concepts (Cole, Gay, Glick & Sharp, 1971; Lancy, 1983; Saxe & Posner, 1983; Schindler & Davison, 1985). It has also been suggested that Native people "underparticipate and underachieve in Mathematics not only because of the cultural differences, but also because of unsatisfactory instructional techniques and materials" (Cheek, 1984a, p. 107).

Therefore, one of the barriers which may block entry to higher levels of education is the practice of using both standardized achievement tests, such as CTBS, and report card marks in Mathematics to stream students into General Math rather than Algebra courses. Such streaming may severely affect Native peoples' access to "equal economic opportunity" through post-secondary education.

## 1.2 RATIONALE OF THE STUDY

Standardized static testing procedures are now widely used to measure intellectual ability and school achievement. Critics of these procedures have suggested other approaches to measuring human potential. Collectively described as dynamic assessment (Brown & Ferrara, 1985; Feuerstein, 1980), these dynamic approaches focus on the interactive role of the examiner and the individual child. Examination of the learning processes allows investigation of how the student processes information rather than on what information has been processed (Leong, 1987).

The use of interactive probing and expert guidance is not a recent approach to assessment of learning processes within school settings. More than fifty years ago, Vygotsky, a Russian psychologist, proposed a dynamic assessment methodology to investigate his conceptualization of an individual's learning potential, which he labelled "the zone of proximal development" (Vygotsky, 1978).

Vygotsky's zone of proximal development examines a child's learning potential from the basis of his or her ability to profit from instruction and to transfer that information to a novel situation (Campione et al., 1984). The extent of instruction needed to affect learning and the efficiency of transferring acquired knowledge to new tasks are considered the prime measure of intelligence (Campione et al., 1984). Even though the use of

dynamic assessment is increasingly discussed in the literature, it is not commonly used as a testing procedure (Brown & Ferrara, 1985).

In order to maximize the educational opportunities of Native people, it is necessary to have a major shift in testing philosophy. Therefore, it is proposed that a learning potential assessment method based on Vygotsky's zone of proximal development could provide valuable information about the learning potential of Native students in Algebra.

## 1.3 PURPOSE OF THE STUDY

The purpose of this study was to use an alternate psychoeducational assessment method to examine learning potential of Indian students in an academic domain, specifically Algebra. Learning, maintenance, and transfer tasks were used to explore internalization processes with the assistance of the following research questions:

1. Can the zone of proximal development yield diagnostic information on individuals' learning processes?
2. Can the zone of proximal development yield diagnostic information on individuals' maintenance processes?
3. Can the zone of proximal development yield diagnostic information on individuals' transfer processes?
4. Are there qualitative differences in the learning, maintenance, and transfer processes for achieving and non-achieving students?

## 1.4 DEFINITION OF TERMS

For the purpose of this study, the following terms are defined.

1. Indian The terms "treaty" and "non-treaty" are defined in Section 2 of the Indian Act and are used for legal arguments. Since the present study has focused on learning potential assessment, the legal status such as treaty and non-treaty has not been differentiated. Although the study selected only treaty Indians from the bands of Beardy and Okemasis, the term "Indian" in this study refers to both treaty and non-treaty Indians.

2. Native Indian, Inuit and Metis people of North America.

3. Zone of proximal development "The distance between the actual developmental level as determined by independent problem solving and the level of potential development as determinded through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 86).

4. Internalization The process by which inter-psychological (between people) functions are transformed to intrapsychological (within a person) functions (Vygotsky, 1978).

5. Learning The efficiency of task performance as demonstrated in problem solving. For the purposes of this study, learning refers to the sequential independent solving of three integer problems involving the addition of negative numbers.

6. Maintenance The capacity of the child to maintain learned skills over a specified time frame. For the purposes of this study, maintenance refers to the retention of the ability to add negative numbers correctly, approximately two days after the introduction of the concept.

7. Near Transfer Problems founded on the use of a related rule or principle (Brown & French, 1979). For the purposes of this study, near transfer refers to the addition of positive and negative numbers. Further, in this study the near transfer task occurs within two days of the learned task and is considered short-term near transfer.

8. Far Transfer Problems related to the use of a new rule or principle (Brown and French, 1979). For the purposes of this study, far transfer refers to the subtraction of negative numbers. Further, in this study the far transfer task occurs within two days of

the learned task and is considered short-term far transfer.

9. Prompts Graduated aids which uncover the "readiness" of students to learn, maintain, or transfer skills (Brown & French, 1979).

10. Integers Positive numbers, negative numbers, and zero.

11. Algebra "A process of reasoning by the use of symbols" (Gove, 1978, p. 52).

12. Mathememathics "A special language that children learn by observing their environment and participating in a variety of experiences involving numbers" (Kramer, 1978, p. 203).

13. Problem solving The process of adding and subtracting positive and negative numbers.

14. Natural meaning units Within the context of the transcripts, "Change of meaning of the situation for the subject that appears to be psychologically sensitive" (Giorgi, 1985b, p. 11).

15. Language Standard English language.

16. Metacognition A person's reflective awareness of cognitive processes.

# CHAPTER TWO

## 2.1 VYGOTSKY'S SOCIO-CULTURAL THEORY OF INTELLECTUAL DEVELOPMENT

Dynamic assessment focuses on processes rather than product, and uses an interactive relationship between the examiner and the student (Narrol & Narrol, 1977). Soviet dynamic assessment is based on Vygotsky's socio-cultural theory of intellectual development.

In pre-revolutionary Russia, psychology was influenced by European science and philosophy stemming particularly from Germany (Kozulin, 1984; Luria, 1979). Psychology was an academic discipline and most practitioners were physicians or philosophers. As part of their academic "rite of passage", it was common to study in Europe. Kozulin (1984) described this as the "European period in psychology".

During this time, two major opposing schools of thought emerged to explain psychological phenomena and, in particular, the concept of consciousness (Cole, 1977). These were the behaviorists (Pavlov, Behterev, Blonsky) and the idealistic psychologists (Chelpanov, Wundt). They split over their respective interpretations of Cartesian dualism, which perceived humans as "machinelike bodies" and "spiritual minds" (Kozulin, 1984).

Their distinctions were evident in the treatment of consciousness. Behaviorists believed in the "total reflexological study of man as the only method that would guarantee objective

results" (Kozulin, 1984, p. 57). They preferred to ignore consciousness and study elementary behavior processess (Cole & Scribner, 1978; Luria, 1979). By contrast, the idealistic psychologists could describe consciousness but could not explain it (Luria, 1982). They appealed to "self-observation, focusing on the sensations, images, and feelings of consciousness" (Kozulin, 1984, p. 85).

Vygotsky described these opposing positions as the "crisis in psychology. . . there exist many psychologies, but there does not exist a unified psychology" (Wertsch, 1985b, p. 4). His interpretation of this crisis continues to be relevant to modern psychology (Bain, 1983; Cole & Means, 1981; Zinchenko, 1985) where there is a distinction made between "mind" and "behavior" (Minick, 1984).

An understanding of his methodology is fundamental to appreciating Vygotsky's theory. Vygotsky was critical of behavioural psychology and felt he had to abandon traditional methods of investigation. He stated that the "criticism of current views concerning the essential nature and development of psychological processes must eventually result in a reexamination of methods of research " (Vygotsky, 1978, p. 58).

Three principles formed the foundation of Vygtosky's methodology (Vygotsky, 1978 & 1981a; Wertsch, 1985b). First, he focused on processes rather than objects.

> Psychological analysis of objects could be contrasted with the analysis of processes, which requires a dynamic display of the main points making up the processes' history. . . . Any psychological process, whether the development of thought or voluntary behavior, is a process undergoing changes right before one's eyes. . . . Our method may be called experimental - developmental in the sense that it artificially provokes or creates a process of psychological development. (Vygtosky, 1978, p. 61)

Second, he attempted to distinguish between explanatory analysis and descriptive analysis.

> Following Lewis, we can apply the distinction between phenotypic (descriptive) and genotypic (explanatory) viewpoints to psychology. By a developmental study of a problem, I mean the disclosure of its genesis, its causal dynamic basis. By phenotypic I mean the analysis that begins directly with an object's current features and manifestation. It is possible to furnish many examples from psychology where serious errors have been committed because their viewpoints have been confused. (Vygotsky, 1978, p. 62)

Third, Vygotsky included a component to examine processes that have become "mechanized" or "fossilized".

> These fossilized forms of behavior are most easily found in the so-called automated or mechanized psychological processes which, owing to their ancient origins, are now being repeated for the millionth time and have become mechanized. . . . Their automatic character creates great difficulty for psychological analysis. . . . The processes that have traditionally been referred to as voluntary and involuntary attention provide an elementary example that demonstrates how essentially different processes acquire outer similarity as a result of automation. (Vygtosky, 1978, p. 64)

One of the most unique characteristics of Vygotsky's methodology is his conceptualization of the nature of development: "When Vygotsky speaks of his approach as "developmental" this is not to be confused with a theory of child development" (Cole & Scribner, 1978, p. 7). Vygotsky's account of development included quantitative and qualitative shifts. Quantitative or evolutionary shifts form "elementary mental functions"; they are a result of biological or innate abilities in humans. Qualitative or revolutionary shifts account for "higher mental functions" and are a result of mediated, internalized interactions (Vygotsky, 1978 & 1981b).

Vygotsky considered "consciousness" to be the highest mental function. He further believed consciousness to be comprised of two

subcomponents: intellect and affect. The influence of "Marx's concern with the development of individual consciousness and alienation in modern society" (Spring, 1975, p. 62) and the "crisis in psychology" led Vygotsky to make consciousness the important construct in his approach (Leont'ev & Luria, 1968; Minick, 1984; Toulmin, 1978). Lawson (1984) credited Vygotsky with "identifying the importance of reflection upon cognitive activity", or metacognition. Lawson (1984) stated that "The activity of consciousness can take different directions; it may illumine only a few aspects of a thought or an act. . . We use consciousness to denote awareness of the activity of the mind - the consciousness of being conscious" (p. 91).

Vygotsky approached the study of consciousness as a methodological problem. He introduced three types of experiences which contribute to the development of consciousness: historical, social and repeated. Historical experience is passed from generation to generation; social experience is learned from other persons; and repeated experience is learning from past experience. Vygotsky (1979a) described these experiences as the social component of our behavior.

Three key concepts emerge from Vygotsky's concern with the social component of behaviour and are therefore important in understanding his concern with the development of "consciousness". They are: mediation, internalization, and zone of proximal development (Vygotsky, 1978 & 1981b).

According to the concept of mediation, "in higher forms of human behavior, the individual actively modifies the stimulus situation as a part of the process of responding to it" (Cole & Scribner, 1978).

Wertsch (1985b) believes that "Vygotsky made his most important and unique contribution with the concept of mediation" (p. 15).

Internalization is another key concept of Vygotsky's thinking (Brown and French, 1979). In this process, interpsychological functions are transformed into intrapsychological functions. "We call the internal reconstruction of an external operation internalization" (Vygotsky, 1978, p. 56).

Internalization is not a transfer model; it is a process model. "The process of internalization is not the transferal of an external activity to a pre-existing internal plane of consciousness; it is the process in which the internal plane is formed" (Leont'ev, 1981, p. 57).

In order to explain the process of internalization, Vygotsky introduced the concept of a zone of proximal development, also called the "zone of potential development" (Brown & French, 1979) or "area of next development" (Leont'ev & Luria, 1968).

Vygotsky defined the zone as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development, as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). Wertsch and Rogoff (1984) described Vygotsky's zone of proximal development as the distance between a

child's independent functioning, or actual development, and his or her collaborative functioning, or potential development. Brown and Ferrara (1985) described the zone as "a map of the child's sphere of readiness, bounded at the lower end by her existing level of competence, but at the upper end by the level of competence she can achieve under the most favourable circumstances" (p. 299).

The zone of proximal development delineates the spatial relationship between interactive instruction and development (Vygotsky, 1978). This concept is at variance with the implicit assumption in most learning theories: if the child isn't learning, there must be something wrong with the child. The zone of proximal development concept shifts the responsibility of the deficit from within the child to the teaching-learning process. Vygotsky theorized that the child's potential developmental level should be assessed separately from the child's actual developmental level, because the two levels vary independently (Vygotsky, 1978).

## 2.2 APPLICATION TO NATIVE EDUCATION

Even though new initiatives have been undertaken in other areas of Native Education, the area of psychoeducational assessment has been neglected. Control of potential culture and language bias is difficult, as standardized tests are indexed to a representative sample of the general population (Seyfort et al., 1980). Attempts have been made to minimize cultural bias by introducing culture-fair tests, but these "usually omit tasks related to school learning

which are critical in the assessment of children" (Seyfort et al., 1980, p. 15).

Fifield and Fifield (1985) outline techniques for controlling cultural and language bias with the use of "non-biased standardized tests" (p. 19). One of the tests they suggest is the WISC-R. However, a controversy exists concerning the use of the WISC-R with Native people (Brandt, 1984a; McShane & Plas, 1984a, 1984b). Research in teacher expectations and their effects on students' performance suggest teachers should interpret WISC-R test scores with caution (Seyfort et al., 1980).

> Professors of education and teacher trainers should bring to the attention of in-service and pre-service teachers of Native learners the need to be open toward the learning potential of these children rather than stereotyping them as low achievers and somehow communicating low expectations to them either explicitly or through subtle gestures (Rampaul et al., 1984).

Several researchers believe that such tests reflect only present knowledge and skills and therefore may result in an unfair measurement of potential (Campione, Brown, & Ferrara, 1982; Feuerstein, 1979, 1980). Brown and French (1979) suggest:

> To improve the predicting and diagnostic power of our tests by the year 2000 we will be forced to consider

> both the child's initial ability and learning potential in a variety of testing formats quite unfamiliar to today's standardized procedures. . . . Armed with such information we should be able to form a far more balanced picture of the child's capabilities than can be revealed by his score on standardized tests (p. 266-267).

Feuerstein (1979) has applied the concepts of dynamic assessment in his Learning Potential Assessment Device. Brown and Ferrara (1985) suggest Budoff's test-train-test procedure is also very similar in nature.

### 2.2.1 SUMMARY OF ZONE OF PROXIMAL DEVELOPMENT RESEARCH

One important principle of Vygotsky's experimental-developmental research method is the analysis of internalization processes. Analysis of processes has been researched by artifically creating or provoking processes of psychological development by introducing learning, maintenance and transfer tasks (Luria, 1961, Vygotsky, 1978). Soviet research has discovered individual differences in children with regard to: the number of prompts they needed to learn a task, their ability maintain a skill after a delay, and the level of assistance needed to transfer the skill to a new situation. This type of research has resulted in methods that differentiate between the abilities of learning disabled and

mentally retarded children to transfer learning to new tasks (Wozniak, 1980).

Outside of the Soviet Union, research using the zone of proximal development as a learning potential assessment method has been limited but has begun to find use as an alternate testing method (Barr, 1988; Delclos, 1987; Pellegrino, 1987). Researchers (Brown & Ferrara, 1985; Brown & French, 1979; Campione et al., 1984; Hall & Day, 1982) extended Soviet work in the dynamic assessment of learning potential by teaching the underlying rules and processes for successful problem solving in pattern matching tasks or in tasks involving geometric designs in learning, maintenance and transfer tasks. (Campione et al., 1985).

In order to compare process and product measures, Brown and Ferrara (1985), and Campione et al., (1984) studied the relationship between dynamic measures and traditional IQ scores by interpreting the zone of proximal development as "efficiency of learning and breadth of transfer" (Brown & Ferrara, 1985, p. 297). The zone was measured by the researcher, who supplied prompts to help students complete the three tasks. The measurement was based on the number of prompts needed to solve problems, and on the amount of assistance required to solve transfer problems. The study assumed that the amount of aid would decrease as each problem was solved, and the slope of the decrease was also used to measure the zone. Results indicated that IQ scores failed to predict almost fifty percent of the children's learning efficiency and/or degree of transfer.

Brown and Ferrara (1985) study revealed several learning profiles:

1. slow learners, narrow transferrers, low IQ (slow)
2. fast learners, wide transferrers, high IQ (fast)
3. fast learners, narrow transferrers, (context bound)
4. slow learners, wide transferrers (reflective), and
5. fast learners, wide transferrers, low IQ (pp. 292-293).

The first two profiles were found to be detectable with traditional IQ testing. However, the last three were uncovered only by dynamic assessment because only the process measure was able to differentiate between learning efficiency and the ability to generalize learning. Dynamic assessment revealed that some students needed fewer prompts to learn tasks than to generalize their learning (context bound), while others needed more prompts to learn tasks than to generalize their learning (reflective). For the last profile, IQ scores underestimated the students' efficiency of learning and their ability to transfer learning.

Campione et al. (1984) explained that "static test procedures typical of most assessment approaches dramatically underestimate the level of functioning that a child can achieve" (p. 89). They suggested that process measures, such as learning and transfer scores are superior to static measures in their ability to predict children's potential to profit from instruction, an important criteria for success in school.

## 2.2.2 PRINCIPLES OF THEORY OF ASSESSMENT OF LEARNING POTENTIAL

This theory of assessment of learning potential is based on two major principles. First, a student's ability to profit from instruction can give valuable information for assessing learning potential. As an individual difference matrix, learning rate or efficiency of learning can be considered important diagnostic information for the purpose of programming. As stated by Campione et al. (1985), "The conclusion is that the readiness to learn, or to profit from instruction within a domain, represents an important dimension along which individuals differ at any given point in time" (p. 299).

Second, a student's ability to transfer training can give valuable information for assessing learning potential. The notion of transfer is "based on the concept of accessibility, or the ability to use flexibly and appropriately the information and skills" (Campione et al., 1982, p. 456). Transfer of training has been researched in North America by using detailed task analyses of both cognitive tasks and possible transfer probes (Brown & Ferrara, 1985; Campione et al, 1985). However, a major problem with transfer of training has become the focus of current research (Brown & Campione, 1986). The problem relates to the notion of stablity of individual differences in elementary mental operations (Brown & Camptione, 1986). It has resulted in the discussion of the importance of domain and the question of whether "transfer was then

due to the set of shared features of the tasks in question" (Campione et al., 1982, p. 462).

This discussion has placed learning potential assessment in academic domains. Campione et al., (1985) explained that the main purpose of intelligence tests is to predict school success; therefore, an examination of learning processes in school might contribute an indirect measure of intelligence. They state, " We are likely to learn more about learning by situating our experiments in contexts in which we can observe responses to guided prompts" (p.453 ). By measuring learning processes in a school context, "learning to learn" can be evaluated. This assessment requires detailed analysis of academic tasks, such as mathematics and reading comprehension, in order to determine the appropriate instructional prompts for ensuring conceptual understanding (Brown & Ferrara, 1985).

## 2.3 QUALITATIVE RESEARCH METHODOLOGY

Selection of the appropriate research methodology is important to the results of any study, and is particularly so in cross-cultural research (Brislin, 1979; Cole & Means, 1981; Laboratory of Comparative Human Cognition, 1979; Lonner, 1980; Shipman & Shipman, 1985). The positivist research paradigm, with its associated quantitative methodology, has inherent methodological problems for cross-cultural studies (Goetz & LeCompte, 1984; Foschi & Hales, 1979).

However, the disciplines of psychology, sociology, and education have primarily adopted a positivist research paradigm for designing and implementing research in the social sciences (Kerlinger, 1964). Kerlinger (1964) defined several important constructs of this method of inquiry: "Scientific research is a systematic, controlled, empirical, and critical investigation of hypothetical propositions about the presumed relations among natural phenomena" (p. 13). He emphasized two points: research is systematic and controlled, and research is empirical.

Kerlinger (1964) stated that the scientific approach does provide a research paradigm to the social sciences for the investigation of natural phenomena. However, the meaning of "natural phenomena" differs in the natural and the human sciences. In the natural sciences, it can include ducks, isotopes, grain, critical mass, etc.; in the social sciences, it includes only humans.

As a result, the quantitative research approach for examining the effects of instructional methods on students, for example, is similiar to that for examining treatment conditions on plants. The experimental design includes identifying independent and dependent variables, manipulating the independent variables to measure the effect on the dependent variable, and interpreting the numerical data by statistical analysis (Kerlinger, 1979). "The central problem becomes one of controlling experimental conditions and developing precise measurements for subsequent statistical analysis" (Maling & Keepes, 1985, p. 266).

Maling and Keepes (1985) suggest that an alternative research methodology is needed to investigate the "forms of knowledge or ways of knowing", as present techniques and approaches are dominated by "paradigms from agriculture botany" (p. 265). This opposition is not new in the social sciences. More than fifty years ago, Vygotsky criticized psychology for "ascending the ladder of science by adapting zoological models as the basis for a new general approach to understanding the development of society" (Vygotsky, 1978, p. 20).

The dissatisfaction with present day methods of investigation is exemplified by the recent creation of the phenomenological branch of psychology. Proponents of this branch of psychology continue to be dissatisfied with the resolution of the Cartesian dualism debate, which is reminiscent of the debate during Vygotsky's lifetime (Kruger, 1981). This concern has resulted in a significant similarity between phenomenological psychology and Vygotsky's socio-cultural theory, that is, the study of consciousness. Spiegelberg (1975) explained:

> "Phenomenology" is, in the 20th century, mainly the name for a philosophical movement whose primary objective is the direct investigation and description of phenomena as consciously experienced, without theories about their causal explanation and as free as possible from unexamined preconceptions and presuppositions. (p. 3)

Phenomenological psychology has two sources: Danish theologian and existenialist S. Kierkegaard, and philosopher E. Husserl (Kruger, 1981). Although Kerkegaard and Husserl were from different academic traditions, they simultaneously rejected natural science as the only science. As well they rejected natural science's method of investigation. Kruger (1981) stated that "Both rejected the reductionistic tendencies of natural science and denied that man could be understood by regarding him as a system of atoms" (p. 22).

Within phenomenological psychology, Giorgi (1971, 1975, 1979, 1985b, 1985c, 1985d) developed a phenomenological-psychological methodology has developed which can be used as a method to analyze data.

> Through a utilization of the philosophical tenets of extistential phenomenology, we are attempting to found psychology conceived as a human science. . . The prime motivation for this attempt is to try to deal with reality within an explicitly human context. More specifically, the issue is to find a means of studying perception, learning, etc. while at the same time being mindful of the human-ness of the subject and the social aspects of the situation. Thus, there is a deliberate attempt to break away from basically physicalistic expressions of the world and to move toward more·experiential descriptions. That is why we

felt that new ground had to be broken for the study of the basic processes ( Giorgi, 1971, pp. xi-xii).

In qualitative research, data is obtained by observing, interviewing, videotaping, and employing other qualitative strategies (Berg, 1989). In interactive research designs, language is often the primary unit of data available for analysis. Miscommunication resulting from dissimilar language meanings is therefore an important concern. As stated by Berg (1989), "Perhaps the most serious problem with asking questions is how to be certain the intentions of the questions have been adequately communicated" (p. 23). The analysis of recorded verbal communications usually assumes that the meaning intent of messages sent has been clearly received if not understood. However, because the researcher's attributed meanings to sayings or actions may be different than the subjects' intentions, misinterpretations of language data is a real possibility (Goetz & LeCompte, 1984). The probabilty of language miscommunication is a critical concern in qualitative research, and the potential for it to occur is increased in cross-cultural contexts.

## 2.4 SUMMARY

Vygotsky conceptualized a unified theory of how people learn. His socio-cultural theory of intellectual development explains that "culture is the product of social life and human social activity"

(Vygotsky, 1979b, p.164). Vygotsky's theory includes a component that allows examination of how culture is transmitted. In other words, the zone of proximal development provides a methodology by which the processes of people's learning can be examined.

Dynamic assessment or interactive diagnosis is one way in which the zone of proximal development research has been applied for the purposes of learning potential assessment. Dynamic asssessment is considered valuable for culturally different students because it allows researchers to "improve the predictability and diagnostic power of our tests" (Brown and French, 1979, p. 270). Improvement of diagnostic power of tests is needed in Native education in order to avoid the routine use of culturally biased standardized tests for making educational decisions.

Psychoeducational diagnosis is not the only area of Native education where there are concerns about methods of investigation. Cross-cultural research has raised specific concerns with quantitative research methodology; and therefore, an alternative research approach may be necessary to avoid generalizing from erroneous data. As stated by Cole and Means (1981), "Of greatest concern to us is the frequency with which the poor performance of a special group on some experimental task is taken as evidence that its members lack a specific ability or process: not just that they do not show it in performing that task under those circumstances but that they lack it completely" (p. 143).

# CHAPTER THREE

## 3.1 RESEARCH DESIGN

The present study was based on zone of proximal development research by Brown and Ferrara (1985) and Campione et al. (1984), who operationalized the zone by using learning, maintenance and transfer tasks to identify potential development. Similar methods were used in this study. However, the tasks were not measured or mapped; instead, they were used to artifically provoke psychological development for the purpose of describing the processes by which the students internalized algebraic concepts.

The present study followed an exploratory case study design, using zone of proximal development methodology as a basis for dynamic assessment of learning potential of Indian adolescents as they were introduced to algebraic concepts. This qualitative design was selected for a number of reasons. First, the qualitative research paradigm allows a study of human life by examining "groups or processes in a fresh or different way" (Goetz & LeCompte, 1984, p.2) and has been used extensively in cross-cultural studies in anthropology and sociology. Second, a qualitative research design is considered an alternative to quantitative designs since qualitative design "presents the possibility of discovery of new meanings in educational situations" (Maling & Keepes, 1985, p. 273). Third, the discovery of "new meanings" is considered important in Indian education, and particularly in mathematics education: " A

survey of the literature relating to the mathematical education of Native Americans strongly suggests that ethnographic studies are essential so that we can better understand the mathematics behavior of Indian students" (Bradley, 1984, p. 103-104). Finally, researchers who have mapped the zone of proximal development using quantitative methods have suggested that further research should be done using a case study design as a research strategy to obtain a large amount of data on a small number of subjects (Campione et al., 1982).

## 3.2 TECHNIQUES EMPLOYED

Brown and Campione (1986) and Brown and Ferrara (1985) have suggested that using zone of proximal development methodology to investigate academic task performance would extend the "diagnostic and prescriptive promise" of this dynamic measure (Brown & Ferrara, p. 298). In the present study, the zone of proximal development methodology has been used to assess the internalization processes of achieving and non-achieving Indian adolescents in Algebra. This type of assessment is considered to be an indirect measure of intelligence (Campione et al., 1985).

For the purposes of this study, Algebra has been chosen as a suitable academic task for the following reasons:

1. it is an important academic subject since Grade Ten

Algebra is a prerequisite for most post-secondary courses;

2. it is considered to be a culture free task since it does not occur naturally in any society (Dr. D. Elias, August 6, 1987);
3. it is considered a suitable problem solving task for adolescents (Dr. V. Lubovskii, May 25, 1987).

## 3.3 SAMPLE

The study examined six Indian adolescents early in their Year Seven Mathematics. This grade level was chosen to ensure that the subjects would not have been introduced to the task of "addition and subtraction of integers" which occurs at the end of the Year 7 program (Saskatchewan Education, 1978). The sample included: two achieving students (one male and one female); and four non-achieving students (two males and two females). For the purpose of this study, the students were classified as achievers or non-achievers by the following criteria:

1. A student was considered to be an achiever if he or she was less than one year below grade level in recent CTBS "Math Overall Score" and had a score of at least 60 percent in Mathematics on the First Report Card.

2. A student was considered to be a non-achiever if he or she was more than two years below grade level in recent CTBS "Math Overall Score" and had a score of less than 60 percent in Mathematics on the First Report Card, or was receiving special Math instruction in the Resource Room.

3. All students in the sample were required to be able to add and subtract numbers 0-20 using a number line and complete problem cards bearing simple equations (e.g., 5 + 3 = ). See Appendix A for these pretest questions.

Permission was received from the Saskatchewan Valley School Division to conduct the research at Stobart High School in Duck Lake. This is a provincial school which services Beardy's Reserve and has a cross-section of achieving and non-achieving Indian students. At the time of the selection, the Grade Seven class had a total of 16 Indian students. Four of the pupils did not meet the classification criteria but fell between the two classifications. The remaining group of Indian students was composed of four achieving males, three achieving females, two non-achieving males, and three non-achieving females.

An arbitrary number of six students was chosen as a reasonably sized sample to be studied using the outlined methodology. In selecting the one male and one female achiever, the researcher

consulted the pupils' Math teacher in order to choose the best Math students. Four non-achievers were chosen: the two males who met the criteria of the study and the two non-achieving females whom the researcher had known previously.

After students were selected, the researcher obtained their agreement to participate in the study by speaking to each one individually. The nature of the study also required that parents' permission be received for students who agreed to participate. Parental or guardian permission was obtained by the Guidance Counsellor at Stobart High, who is an employee of the Beardy's and Okemasis Band Council and a member of the Beardy's Reserve.

To obtain a favourable response to the request for permission, the researcher asked the guidance counsellor, who knew the families and the community, for assistance in determining the most effective method. It was decided to have home interviews which were conducted in the Cree language. She visited the homes of the six students in order to explain the testing, and to receive parental or guardian permission to work with the students. All six parents or guardians gave their permission. A date and time was established during which the researcher would be available at the school should additional information be required. One parent required additional information.

## 3.4 GUIDELINES

Data was gleaned from videotape and audiotape transcripts during all task interactions, as well as from metacognitive interviews following completion of tasks. Documentation of study results was kept in the form of videotapes, audiotapes, and completed problem cards. As the present study followed a dynamic, or interactive process of assessment, the students were encouraged to ask and answer questions and therefore participate in problem solving. If they didn't understand an explanation, they could ask for additional information. Their queries were then incorporated into the analysis of the study. This format differs from static standardized tests where the student's questioning is not considered data.

The students were encouraged to use the correct terminology as they worked through the task. As stated by Vygotsky (1986):

> Words and other signs are those means that direct our mental operation, control their course, and channel them toward the solution of the problem confronting us . . . . Learning to direct one's own mental processes with the aid of words or signs is an integral part of the process of concept formation (p. 106-108).

However, the students were not introduced to the term "integer line" which was instead called a number line. It was felt that knowledge of the term "integer line" was not necessary in order to

solve the problems of addition and subtraction of positive and negative numbers.

Three types of problems were presented during the course of the study: adding two negative numbers for the learning and maintenance tasks, adding a positive and a negative number for the near transfer task, subtracting a negative numbers from a positive or negative number for the far transfer task. For each problem type, the specific problems were given to the students in the designated order (see Appendices A, B, C, and D). For each of the tasks, the student solved three problems correctly in sequence before the next task was introduced.

The research design initially proposed that a similar sequence of prompts would be followed for each student in learning and transfer sessions, and that additional prompts would be used when warranted by the interaction. This structure was modified during the testing. The prompts were followed in a strict, sequential manner during the learning task. During the maintenance task, as expected, the prompts were not used. During the near and far transfer tasks, however, students tended to perform the task without the need of all the prompts in the sequence. As well, even though the researcher used the sequence of prompts as a framework, the student's questions and responses led the researcher to provide additional and varied prompts in order to assist him or her in the internalization process.

The metacognitive data was collected by using a nonscheduled standardized interview format. This process recognized individual

differences and allowed the use of different probes for different students. Denzin (1970) described the nonscheduled standardized interview as one of the best formats for exploratory studies, describing the procedure as a "focused interview in which certain types of information are desired from all respondents but the particular phrasing of questions and their order is redefined to fit the characteristics of each respondent" (p. 125). The format makes it possible to raise "important issues not contained in a schedule" (Denzin, 1970, p. 125). Maling and Keepes (1985) describe this procedure as "open-ended and conversational interviews. . . guided self-reflection" (p. 275).

## 3.5 MATERIALS

The following materials were used during the course of the study. The vocabulary cards, pretests on addition and subtraction, concrete number and integer lines, and problem cards were designed specifically for this study.

1. Recording material - Videocamera, videotapes, VCR, television, tape recorder, audiotapes, pens.
2. Vocabulary cards - numbers, number line, negative numbers, positive numbers, less than, greater than, negative 1, positive 2, and inverse.
3. Pretest on addition and subtraction cards (see Appendix A).
4. Marble as a counter for number lines.

5. Concrete number line (see Figure 1).

6. Concrete integer line (see Figure 2).

7. Problem cards (see Appendices B, C, and D).

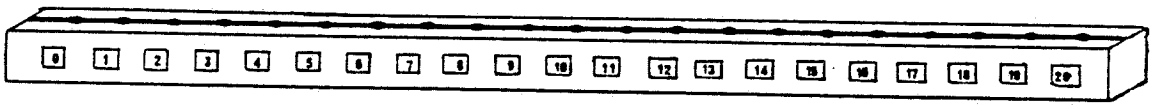


Figure 1: Concrete number line

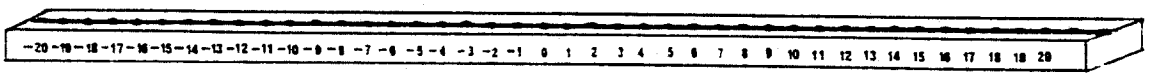


Figure 2: Concrete integer line

## 3.6 DATA COLLECTION

Each student participated in three separate sessions; the last session was scheduled one week after the first session. The second session was scheduled midway between the first and last sessions.

### 3.6.1 FIRST SESSION

The purposes of the first session were to establish rapport between the researcher and the student, to review the number line, to ensure that each student had the necessary computational skills, and to desensitize students to the videocamera. Because the researcher had taught at Duck Lake, most of the students knew her; however, she had taught only one of the students (one of the non-achieving males). Some time during the first session was set aside for renewing acquaintances and for explaining the purpose of the sessions and the dynamic assessment procedures. Students were encouraged to ask and answer questions.

The session began with the researcher and the student working with the videocamera and the tape recorder. The researcher demonstrated the
videocamera to the student, and a discussion session was taped and shown to the student before the pretest on addition and subtraction was completed. The student was informed that the videotape of the remaining sessions would not be reviewed until the testing for all the students was finished.

It was particularly important that each student be familiar with addition and subtraction using the concrete number line as it was to be used as an aid in the following sessions. In order to ensure that each student was able to use this device, each was asked to repeat the pretest with the assistance of the concrete number line. After this was completed, the student was asked to write the answer on problem cards. The cards were presented in the same order to each student (see Appendix A).

### 3.6.2 SECOND SESSION

This session was considered the learning session. During the session the procedures of prompting and metacognitive questioning were introduced. The second session was held two days after the first and began with a review of the number line and the utilization of the line for problem solving.

#### 3.6.2.1 Learning Data

Appendix B gives information on the sequence of problem cards and prompts. During the second session, the student was presented with the first problem card, and asked to write down the answer. If the student answered correctly, the next problem in the sequence was presented. The sequence of hints or prompts was initiated if the student could not solve the problem. Instructions were given about the prompting procedure so that students understood that they had

the opportunity to answer the problem after each prompt. Not all of the prompts were given to all of the students because some students solved the problem before all the prompts were given or did not require all the prompts (ie. may have used prompts 1, 2, 5). If a student required further information on a prompt, it was given. For example, Sid, a non-achiever, after being given Hint #1 during the learning task (see Appendix B) asked, "This is a negative?" The examiner affirmed that the number was a negative. Sid's questioning was considered data to be analyzed. The session continued until the student solved three problems correctly in a row. No student required more than four problems to achieve this criteria.

### 3.6.2.2 Metacognitive Data

After the third problem was solved without assistance, the problem cards were shown to the student and each student was asked to explain how the problem had been solved, his or her perception of solving different problems, and his or her perception of a rule for solving the problems. As part of the nonscheduled standardized interview format, the following questions were used as a general framework:

1. Can you tell me how you solved these problems?
2. Was there a difference in solving the second problem from the first problem?
3. If you wanted to explain how you solved these problems using a rule, what would it be?

### 3.6.3 THIRD SESSION

This session was the last session. It occurred one week after the first session. Maintenance, near and far transfer, and further metacognitive data were gathered during this session.

#### 3.6.3.1 Maintenance Data

Problems following the same sequence and similar to ones solved during the learning session were given to each student (see Appendix B). Because it was important that the student not be given the identical problems administered in the learning task, each student began with the problem in the sequence that followed the last problem he or she had solved in the learning task. No student was given problems they had solved previously; the researcher could therefore conclude that each had internalized the skill they had learned. The session continued until the student solved three problems in a row without assistance.

#### 3.6.3.2 Metacognitive Data

After solving three problems without assistance, the problem cards were shown and the students were asked to explain how they solved the problems. To investigate the student's perception of maintenance each was asked:

1. Can you tell me how you solved these problems?
2. Are you familiar with these problems?

3. If you wanted to explain how you solved these problems using a rule, what would it be?

### 3.6.3.3 Near Transfer Data

In this part of the third session, the student was presented with a type of problem different from the learning/maintenance problems. Appendix C gives the sequence of near transfer problems and prompts.

It was hoped that the student would transfer skills learned from "adding two negative numbers" to solve the new problem of "adding a positive and a negative number". The student was presented with the first problem and asked to write the answer.

This procedure is similiar to the learning and maintenance task sessions. If the student answered correctly, the next problem in the sequence was presented. If the student could not answer the problem, the prompting procedure was initiated. The sequence of prompts was used as a general framework. If the student required further information on a prompt, it was given. If the student asked a question, or responded to the researcher's question in a manner which required the researcher to alter the sequence of prompts in order to assist the internalization process, this alteration occurred. The session continued until the student answered three problems in a row without assistance.

### 3.6.3.4 Metacognitive Data

After three problems were solved without assistance, the problem cards were shown and the student was asked to explain how she or he had solved the problem. To investigate the student's perception of near transfer each was asked:

1. Can you tell me how you solved these problems?
2. Are there any similarities or differences between these problems and the ones you did earlier today?
3. If you wanted to explain how you solved these problems using a rule, what would it be?

### 3.6.3.5 Far Transfer

Appendix D gives the sequence of far transfer problems and prompts. The far transfer task was not initially included in the design for this study. It was added after the second session when it was felt that more information could be obtained if a far transfer task was included.

The far transfer task was the third part of the third session. The student was presented with the first problem card, and asked to write the answer.

This procedure is identical to the near transfer tasks methodology. If the student answered correctly, the next problem in the sequence was presented. If the student could not answer the problem, the sequence of prompts was employed as a framework, but the student's responses and questions were used as the matrix for

determining which prompts were necessary for his or her internalization processes. The session continued until the student answered three problems in a row without assistance.

### 3.6.3.6 Metacognitive Data

After the three problems were solved without assistance, the problem cards were shown and the student was asked to explain how she or he had solved the problem. In order to investigate the student's perception of far transfer, the following questions were asked:

1. Can you tell me how you solved these problems?
2. Are there any simillarities or differences between these problems and the ones you solved earlier today?
3. If you wanted to explain how you solved these problems using a rule, what would it be?

## 3.7 INSTRUMENTS

The addition of integers was chosen as a task because it is considered to be a difficult concept for students to acquire and might be useful for evaluating learning potential in Algebra (Dr. J. Beamer, July 9, 1987). Bashaw (1972a) and Kuchemann (1985) stated that Algebra screening tests are not considered useful in predicting students' success in Algebra courses. Therefore, it was necessary to devise an instrument for use in the present study . Addition and subtraction of integer problem cards and the

nonscheduled standardized interview format are the instruments that were used in this study (see Appendices B, C, and D).

The researcher developed the sequence of integer problems by selecting questions from the following Algebra text: Algebra (Keedy, Bittinger, Smith, & Orfan, 1984). For the learning and maintenance tasks, the problems were sequenced to vary their level of difficulty; the sums of the problems were less than or greater than ten (see Appendix B). In the near transfer task, the problems were sequenced to vary their positive addend to be less than or greater than ten (see Appendix C). For the far transfer task, the problems were sequenced to vary the three types of problems (see Appendix D).

## 3.8 PILOT STUDY

The instruments were field tested with three Grade 7 students at Hague, Saskatchewan. In this particular group, none of the students were designated "non-achievers". Two were "achievers" and the third was experiencing difficulty in mathematics. This student was considered to be the lowest achiever in the group, but did not fall within the parameters of either definition.

As the primary concern was to test the prompting procedures, the level of difficulty of the transfer problems, and the metacognitive data collection, the pilot study was conducted by incorportating the three sessions into one. Therefore, maintenance

was not tested. The field tests resulted in modifications to the transfer task. A far transfer task was also tested in the pilot. Since this task appeared to be quite difficult, modifications to the prompting component were made which allowed the task to be placed in the final study.

## 3.9 DATA ANALYSIS

In the research design, it was proposed that the data be analysed at two levels:

1. all six students would have their zone of proximal development "mapped" using the "Learning/Maintenance/ Transfer" profile similiar to that used by Brown and French (1979), Campione et al. (1984), and Hall and Day (1982);
2. there would be further analysis of two to four students' metacognitive data using Giorgi's phenomenological approach.

After the research was completed, both levels of analysis were incorporated using Giorgi's psychological phenomenological method to describe the internalization processes for all six students during learning, maintenance, and transfer sessions, as well as during metacognitive interviews. Although this method was more complicated, it was felt that more information could be gleaned than from the data than the proposed "mapping" of the profile.

The profile was not considered adequate primarily because of the exploratory nature of this study, which focused on interactive or dynamic assessment of learning processes. The students were encouraged to ask questions and thereby participate in the problem solving. The intent of this focus was to maximize the possibility for variety of responses. A quantitative mapping of the zone would have required a more restrictive response and thus have been less sensitive to the new inputs. A numerical description of an individual's problem solving processes does not give as much information as a qualitative phenomenological methodology revealed.

Giorgi's (1975, 1979, 1985c, 1985d) phenomenological approach to the study of "human science of psychology" provided the framework for data analysis in this study. Giorgi (1975) suggested that the method be utilized to analyze people's self-description of "their everyday activities and how the learning is accomplished" (p. 84).

Even though Giorgi (1975) initially avoided education and academic contexts, he later suggested that his psychological phenomenological method was developing, and could therefore be extended to different contexts (Giorgi, 1985b). He said, " I can honestly state that there has been a radical transformation on my understanding between 1970 and today, and I have to assume that an equally radical change may ensue between today and, say, 1990, but I know of no way of getting there other than by working at it" (Giorgi, 1985b, p. ix). The present study extends Giorgi's method to an educational context. Giorgi's psychological phenomenological

method was used as a model to assist the researcher to interpret the data in a different manner. This interpretation involved the approach of adopting a phenomenological framework to reach an understanding of each individual student's perspective during the learning, maintenance, and transfer tasks. This approach differs from Giorgi's traditional analysis of a person's self- description of learning, but it allows the researcher to observe the structure of the internalization process during the specific tasks.

## 3.10 DATA ANALYSIS RATIONALE

The method outlined by Giorgi was used as a framework for the data analysis of the learning, maintenance and transfer tasks, as well as for analysis of the metacognitive data gathered in this study for the following reasons:

1. Vygotsky's zone of proximal development is a theoretical construct that provides a vehicle for the examination of the internalization processes. Vygotsky's premature death did not allow him significant time to operationalize his method to analyze these processes. However, since the intent of the present research was to examine processes by which Indian adolescents internalize alebraic concepts, Giorgi's method provided a means by which the researcher could unlock the verbal and nonverbal protocols (descriptors of videotape data) . Since the study of phenomenology "is the study of

the structure, of the consciousness to which any thing, event, or person appears" (Giorgi, 1975, p.83), the method outlined by Giorgi provided access to the internalization processes within the individual student.

2. There were two types of data: learning, maintenance, and transfer data; and metacognitive data. Using the same method of anlaysis made it possible to contrast the student's internalization of concepts and the student's consciousness or self-perception of these processes.

## 3.11 DATA INTERPRETATION

Five steps were required to interpret the data. The first step was to transcribe the audio and videotapes. The second step was to read the verbal and nonverbal protocols to obtain an overall impression of the natural meaning units expressed by the students. As any structure from the perspective of the study would have interfered with determining the themes, none was imposed during this interpretation. Giorgi (1985c) describes this step as obtaining a "sense of the whole" (p. 10).

In the third step, the researcher categorized the meaning units from the individual's reactions. The criteria for classifying the meaning units were the individual's verbal and nonverbal responses, questions, or answers which could have signalled a step in the internalization process (see Appendix E). The meaning units were transformed into themes (see Appendix F).

In the fourth step, the researcher examined the themes within the context of the research questions. For example, during the learning task, the research question, "Can the zone of proximal development yield diagnostic information on an individual's learning ability?" was used to establish the framework for interpreting the data. In this step, it was important to deal with each research question separately to avoid confusing the interpretation of the data (Giorgi, 1975). This level of analysis resulted in a description of each student's internalization processes from the perspective of the research questions during the learning, maintenance and transfer tasks (see Appendix G).

In step five, each of the student's learning, maintenance and transfer processes were compared by charting descriptive phrases. "The insights contained in the transformed meaning units into a consistent description of the psychological structure of the event" (Giorgi, 1985c, p. 19) were described.

## 3.12 VALIDITY AND RELIABILITY

Yin (1989) has specified tactics for ensuring that case study research design has validity and reliability.

In terms of validity, there has been an attempt to utilize:

a. "multiple sources of evidence" as school records, pretests and prelessons, problem cards, videotapes, audiotapes, transcripts;
b. "pattern matching" as the description of the

learning, maintenance and transfer processes for providing a comparison among the individual students; and

c. "explanation building" by analyzing the case study data to investigate the qualitative differences in the learning/maintenance/transfer processes for achieving versus non-achieving students.

To ensure that the design of the study had reliability, videotapes, audiotapes, pretests and problem cards, and field notes were retained as the data base. Outlined procedures were followed, and are described in this thesis to allow replication of this study. However, in terms of the reliability, it must be stressed that:

> The chief point to be remembered with this type of research is not so much whether another position with respect to the data could be adopted (this point is granted beforehand), but where a reader, adopting the same viewpoint as articulated by the researcher, can also see what the researcher saw, whether or not he agrees with it. That is the key criterion for qualitative research (Giorgi, 1975, p. 96).

In other words, Giorgi's interpretation of reliability for qualitative research is based on the reader's understanding of the researcher's interpretation of the data. Reliability is not affected if a reader interprets the data differently, or if the

reader does not agree with the researcher's interpretation. Since the present study used Giorgi's phenomenological-psychological method for data analysis, his interpretation of reliability has been adopted.

## 3.13 PROTECTION OF STUDENTS

All personal information obtained during this research study was considered confidential; the student names given in this report are fictious (Social Science and Humanities Research Council of Canada, 1989).

# CHAPTER FOUR

## 4.1 RESULTS

Three components of the research design were important in obtaining the results. First, zone of proximal development methodology artificially created or provoked processes of psychological development (Vygotsky, 1978). Learning, maintenance, near transfer and far transfer tasks allowed investigation of the processes of internalization of the algebraic concepts that were introduced. Second, the qualitative research design provided an alternative research paradigm with which to investigate the internalization processess. Because of the exploratory nature of this study, the choice of this paradigm allowed the researcher to fit the study to the students, rather than fitting the students to the study. The importance of this research paradigm was illustrated in the interaction between researcher and students that resulted in the selection of a data analysis that differed from the original design. Third, Giorgi's (1975, 1979, 1985b) approach to analysis of the verbal and nonverbal protocol data provided a method for uncovering the internalization processes of the students as they worked on the tasks.

The results of this multiple case study are presented using the approach outlined by Yin (1989). Yin suggested that each individual case study need not be presented. Rather, multiple case studies may choose a reporting style labelled a "cross-case analysis" whereby

the information from each case is dispersed throughout separate sections that represent pertinent areas of the study. This format was chosen because of the extensive amount of data that could have been presented.

In the cross-case format, salient features of selected case studies were synthesized or compared under four major headings. These features or themes were selected because they related to the research questions' focus on the efficacy of zone of proximal development methodology to obtain diagnostic information. The identified themes were: introductory information and individual traits, achieving versus non-achieving characteristics, efficient versus inefficient characteristics, and metacognitive questioning. A summary of the students' individual characteristics in relationship to the above themes is specified in Table 1, (see Table 1).

## 4.2 INTRODUCTORY INFORMATION AND INDIVIDUAL TRAITS

The purpose of this section is to give the reader some insight into the unique characteristics displayed by individual students at some point during the three data gathering sessions. These insights should assist the reader in understanding influences that may have affected the students' problem solving abilities and therefore serve to make the remaining case study information more meaningful.

Table 1 Summary of Individual Characteristics

| Student | Achiever/ Non-achiever | Self-Confidence | Problem Solving | Verbal/ Non-verbal | Language Usage | Questioning | Risk Taking | Rule Generation |
|---|---|---|---|---|---|---|---|---|
| Zo | Achiever | Not confident | No pattern | Verbal | Strong - sub-vocalization | Changed- Procedural, Clarification, & Hints | No | Process |
| William | Achiever | Confident | Efficient | Verbal | Strong | Not evident | Not evident | Process |
| Carol | Non-achiever | Confident | Efficient | Non-verbal | Weak - used for problem solving | Clarification, & vocabulary | Yes | Process |
| Kenneth | Non-achiever | Passive | Didn't finish far transfer | Non-verbal | Weak | Procedural- decreased in far transfer | Not evident | Process |
| Mary | Non-achiever | Self-conscious | Confused + and - | Non-verbal | Average | Vocabulary | Yes - changed | General |
| Sid | Non-achiever | Change from independent to cautious | Learning to learn | Non-verbal | Weak - used for problem solving | Changed - clarification & Vocabulary | Yes - changed | Process |

ZO

At the time of the study, Zo was a 12 year 3 month old female selected as "achieving" because her First Report Card mark in Grade Seven Mathematics was 79 and her CTBS Grade Equivalent was 6.4 (June, 1987), placing her five months below her grade level.

(1) Self-confidence

As early as the introductory session, Zo appeared to lack confidence. She tended to seek clarification even when asked to complete such simple tasks as reading numbers. Poor self-confidence appeared to be further demonstrated by a dependence on social acknowledgement throughout the sessions. However, although Zo demanded support, she sometimes misinterpreted the intent of the researcher's actions. For example, on one occasion when the researcher smiled encouragement, Zo asked whether she was solving the problem correctly.

Zo also appeared to require emotional support to complete the tasks. During the far transfer task, the researcher attempted different strategies to assist Zo: offering encouragment, echoing her answers or questions, asking her to stop and think, joking with her, suggesting that she trust her instinct, and finally, jokingly suggesting to her that she wasn't leaving until she solved the task. In retrospect, the latter strategy could be interpreted on the surface as a threat, but it was effective; Zo proceeded to solve the

next three out of four problems, thus allowing collection of further metacognitive data and, ultimately the completion of testing. The effectiveness of this strategy could have been the result of Zo's need for an established boundary rather than for more encouragement. She continued to depend on external assistance throughout the period of data collection.

(ii) Problem Solving Abilities

It was difficult to determine a pattern in Zo's problem solving during the testing, and it wasn't until the data were being analyzed that one became evident. Indeed, the pattern might be described as "no pattern". An example of this "no pattern" was seen in the far transfer task, in which Zo displayed inconsistent problem solving strategies (see Appendix D for the problems referenced). For example, she would use her near transfer rule (Problem 5), add the inverse incorrectly (Problem 6), then revert to near transfer rule (Problem 7). During Problem 11, Zo first answered correctly, but then changed her answer by substituting the inverse for the first numeral, as well as for the second numeral which is an error that she had not made previously.

Zo did not remember having used the number line in school or even having seen one prior to participating in this study. Her lack of experience with the number line probably accounted for her difficulty in using this aid for problem solving in the sessions.

Even though Zo apparently had the prerequisite skills for learning Algebra, she did not utilize or apply them during the three

sessions. There appeared to be an interference with Zo's natural problem solving abilities. During the learning task, Zo requested all the hints, despite the possibility that she might have been able to solve the problem when she had alluded to the correct answer after Hint 2.

In summary Zo's lack of self-confidence was characterized by an unwillingness to take risks: she would request hints, change her correct answers, and, during most sessions, not problem solve without asking procedural questions.

## WILLIAM

At the time of the study, William was a thirteen year old male selected as an "achiever" because his mark was 84 in Mathematics on his First Report Card and his CTBS Grade Equivalent was 7.0 (November, 1986) placing him seven months above his grade level.

### (1) Self-confidence

During the introductory session, William demonstrated a good sense of humour; he was able to easily understand interactive diagnosis, and to solve the problems. William appeared to be a quiet person, but his sense of humour, self-confidence and proficient use of language was displayed in his responses to the researcher's questions. He often answered the questions with more details than the intent required. For example, when he was asked what the figures were called, William replied "squares with numbers

on them"; the answer "numbers" would have been sufficient. This level of response was further demonstrated when he was asked to read the numbers to be placed on the concrete number line, which were not in numerical sequence. He replied "Zero to 20".

(ii) Problem Solving Abilities

William displayed efficient problem solving abilities by accomplishing the learning task without the prompting procedure. However, when he was asked "If you wanted to explain how you solved these problems using a rule, what would it be?" (learning metacognitive question 3, see Appendix B), William could not articulate a rule; his initial answer was "I don't know". This appeared to be an unusual answer for him and a subsequent series of questions revealed that William felt he didn't know a rule because there wasn't a rule. At one point, William stated that "they all follow the same concept just that the numbers are different." He added that he did not know the concept. William's sense of humour was demonstrated when he was given the opportunity to ask questions to help him conceptualize. His first question was "What's the concept?", accompanied with laughter. Yet, William could not verbalize the rule. He said, "I don't know how to put it into words or something."

William's sense of mathematical concepts and his self confidence allowed him to guess at the first problem. The researcher reinforced his correct answer and William correctly

answered the next two problems. However, William would not attempt to articulate a rule. This could be due to the possibility that he would not take a chance by guessing at the rule. It may also be that verbal rule generation is independent of problem solving; that is, a concept may be demonstrated by someone who cannot verbalize the concept.

William responded to the same question, "If you wanted to explain how you solved these problems using a rule, what would it be?", (maintenance metacognitive question 3, see Appendix B) during the next session with a clearer understanding of the rule. He stated, "By adding the two negative numbers together, you get a negative". William could not explain why he was better able to articulate the rule after the maintenance task than in the previous session.

However, William had previously responded to the question, "Are you familiar with these types of problems?" (maintenance metacognitive question 2, see Appendix B) by replying "Not really". Further questioning revealed that William had never seen these problems in school, but had been reading the Algebra section of the World Book Encyclopedia at home, which "tells me how to do them". William further explained that his Dad had shown him the section, which he had read in the two days since the last session. When asked if his interest had anything to do with the fact that we were working on Algebra, William replied that he had previously looked at the Algebra section and recalled that it discussed "numbers with letters from the alphabet like 2X something."

It was not determined whether William's reading of the encyclopedia coincided with the beginning of the research study. At any rate, this was not as important as the fact that William was better able to articulate a rule during the maintenance session than he was in the learning session. This increased ability may have been the result of assistance from his Dad and the encyclopedia, or the two day delay could have given him the opportunity to reconsider the rule.

## CAROL

At the time of the study, Carol was a 14 year 7 month old female selected as "non-achiever" because she was enrolled in Special Math in the Resource Room and her CTBS Grade Equivalent Score was 5.3 (January, 1988) which placed her two years and two months behind her grade level.

### (i) Self-confidence

Carol displayed a quiet confidence. She would respond to the examiner's questions or explanations nonverbally, but when she didn't understand, Carol would question. During the sessions, Carol tended to act passively and non-communicatively; she responded by nodding or answering "yep", "yeah", or "uh". At times Carol appeared tired, frequently yawning and rubbing her eyes.

(ii) Problem Solving Abilities

Carol had some difficulty completing the tasks in an error free manner. Her difficulty with basic skills did not appear to affect her efficient problem solving during the subsequent tasks since she was able to solve the learning problems without the prompting procedure being initiated.

When presented with the first problem [ -5 + (-3)= ], Carol asked, "Is that a take-away 5 or is that just a line?". The examiner encouraged Carol to answer the question without assistance, which she did by writing -8. When asked to read her answer, Carol looked closely at the card and replied "Um, Zero takeaway 5 plus 3, um, the answer? Zero takeaway 5 plus 3." Even though Carol had not internalized the rule of adding two negative numbers, she demonstrated confidence and problem solving skills by asking a clarifying question and then writing an answer. The manner in which she interpreted her answer as " Zero takeaway 5 plus 3" was also very creative. One way in which to understand her answer is to assume that Carol actually invented the integer line in her mind in order to understand the correct answer to this problem. Negative 8 on the integer line is "Zero takeaway 5 plus 3". Carol's possible invention of the integer line may have been facilitated by the introduction of the number line during the first session.

Carol had some difficulty completing the required tasks since she experienced difficulty with basic skills including understanding directions, placing the numbers on the number line from left to

right, placing the zero on the number line, adding and subtracting to the automatic level, substituting numbers, and confusing operations signs. However, Carol compensated for her difficulties by asking clarifying questions, self-correcting, reading the problems aloud to herself, and using the number line to solve the problems.

## KENNETH

At the time of this study, Kenneth was a 13 year 7 month old male selected as "non-achiever" because he was enrolled in Special Math in the Resource Room and his CTBS Grade Equivalent Score was 4.8 (June, 1987) placing him two years and one month behind his grade level.

### (i) Self-confidence

During all of the sessions, Kenneth used nonverbal communication and tended to be hypoactive. It was difficult to determine his level of confidence because of his non-demonstrative behaviour. An example of his passivity occurred when he was asked to place numbers in the correct order. Kenneth initially forgot the zero and didn't realize his mistake until the 20 was in place. Kenneth shrugged his shoulders and then placed the zero after the 20. Alhough Kenneth realized his mistake, he appeared content to leave the zero in the incorrect position in order to finish the task. After a series of questions, Kenneth changed the order

appropriately and informed the researcher that he was used to a number line beginning with number one.

Kenneth did not finish the far transfer task since he completed only two of the required three items in a row (problems 15 and 16, see Appendix D). Testing was discontinued at this time because Kenneth was becoming less and less responsive and the researcher wanted to finish the testing on a positive note instead of risking that Kenneth would withdraw physically.

Kenneth's passivity was evident during all three sessions but it increased during the far transfer task. This behaviour was probably a result of his finding the task very difficult. However, if Kenneth placed the zero in the wrong numerical position to finish a task, it follows that he might also have had the tendency to withdraw when tasks become difficult. Kenneth's passivity or withdrawal appeared to be an effective coping technique used to control his level of participation in the testing situation.

(ii) Problem solving strategies

Kenneth had some difficulty with basic operations such as substituting multiplication for addition, reversing numbers on the problem cards and using the number line. Kenneth's weak language abilities contributed to his misunderstanding of questions and prompts. Combined with his weaknesses in basic skills, his weak receptive and expressive language probably contributed to his limited problem solving strategies. However, during the first and

second sessions, he did ask questions such as "Do I move the marble?". For one subtraction problem, Kenneth asked if he was using the number line correctly.

At the conclusion of the first session the examiner asked Kenneth if there were any problems. He admitted that subtraction was a difficulty for him even while he was using the number line. He further admitted that subtraction had always been a problem. Further discussion revealed that Kenneth's subtraction was not at the automatic level, although he was able to complete the problems by counting in his head. This disclosure did not come as part of the formal metacognitive data collection; however, it was one of the best examples of a student's description of problem solving gathered during the study.

Kenneth, along with Sid, Mary, and Zo, had difficulty with the far transfer items. However, Kenneth was the only student who consistently internalized one type of far transfer item. An example of this type of problem was [ -5 - (-2)= ] which, on the second step of problem solving, is similiar to the near transfer task in that the order of the negative and positive numbers are reversed. One reason why Kenneth could correctly solve this particular type of far transfer problem, and yet not solve the other two types of far transfer problems (see Appendix D), would be that this type of problem was the narrowest transfer of skills from the near transfer task. Solving the other two types of problems would have meant a further transfer, of which he was not capable.

MARY

At the time of the study, Mary was a 12 year 9 month old female selected as "non-achiever" because her mark was 40 in the Grade Seven Math on her First Report Card, and her CTBS Grade Equivalent Score was 4.8 (June, 1987), placing her two years and one month below her grade level.

(I) Self-confidence

Mary began the introductory session cautiously, stating that she did not know what the figures presented to her were called. However, she laughed when the examiner told her the figures were called numbers and, to the researcher's encouragement, she nodded and smiled. It was evident that she might have thought the question referred to something more difficult. Though Mary's cautious behaviour seemed to disappear during later sessions, her self-consciousness did not disappear. This was demonstrated by Mary's reliance on using her fingers for addition and counting beneath the table.

(II) Problem Solving Abilities

Throughout all the sessions, Mary had difficulty using the number line for problem solving. She demonstrated efficient problem solving strategies during the learning and near transfer tasks, but during the far transfer task, when she began to experience

difficulty, Mary became very inefficient. She was able to solve the initial learning problem after the first hint, which introduced the concept of negative numbers (see Appendix B). Mary was able to solve the first near transfer problem (8 + (-3) = ) after Hint 9, first asking whether the answer would be a negative, and then answering her own question by saying "No", and giving the correct answer of 5. Mary's confusion between negative and positive numbers continued.

During the far transfer task (see Appendix D), Mary worked with 16 problems in order to correctly answer three in a row. At the beginning of the far transfer items she felt comfortable enough to respond with a written answer after each hint. However, her confidence appeared to decrease after problem 5 as she became less responsive and wouldn't answer as readily. It was apparent that she confused positive and negative numbers; she had to be reminded that 4 and -4 are two completely different numbers (problem 5). Even though Mary agreed with this point by saying, "(the) negative does make a difference," she continued to confuse the two types of numbers. Examples of this confusion were : problem 8, where she answered 7 for -7; problem 11, where she answered 11 for -11; and problem 12, where she answered 6 but wrote -6 on problem card. Far transfer metacognitive question 2 (see Appendix D) data collection revealed the cause of Mary's confusion. She said, "I was ignoring the negative sign. . . I just forgot".

Her inefficiecy during the far transfer task could also be attributed to her personality. When the task became difficult, Mary

tended to give up. At the close of the testing, Mary responded to the researcher's question about the difficulty of the problems by saying that she didn't really like hard work. When asked why not, she laughed and replied "Cause, it's hard." It should be noted that her tendency to withdraw could be a result of negative experiences in school, and does not necessarily reflect her personality in other situations.

SID

At the time of the study, Sid was a 12 year 4 month old male selected as "non-achiever" because he was enrolled in Special Math in the Resource Room and therefore did not receive a mark on his First Report Card for Grade Seven Mathematics. His CTBS grade score was 4.8 (June, 1987) which placed him two years and one month behind his grade level.

(1) Self-confidence

During the introductory remarks of the first session, Sid appeared to be quite independent and more comfortable using nonverbal rather than verbal communication as he nodded agreement to instructions and would not establish eye contact. His self-confidence varied depending on the difficulty of the task. Sid did not complete an error free introductory session since he substituted multiplication for addition, reversed the order of the numbers when reading the cards, used his fingers to add, and

self-corrected an addition problem. For the majority of the problems using the number line, Sid counted visually instead of using the marble.

Throughout the session, Sid appeared to be quite anxious to finish the tasks quickly. He was independent and felt comfortable manipulating objects. For example, when the researcher was introducing the first session, and before any instructions concerning the number tiles, Sid playfully placed the tiles in the correct numerical order while listening to the opening remarks.

(ii) Problem Solving Strategies

Sid is an example of a student who could be described as "learning to learn". As the tasks became more difficult, Sid appeared to internalize and apply the concepts. In addition, Sid's confidence level appeared to decrease and he became more cautious, requesting hints
during problem solving and changing his reasoning when questioned. Sid's motivation to do well during the tasks seemed to increase, and this increase was reflected in his cautious behavior.

During the learning task, Sid solved the first problem after Hint 3. For the near transfer task, Sid's behaviour changed as he requested all the hints, even though he actually solved the problem after Hint 2.

Data analysis revealed that Sid came very close to understanding the concept that the subtraction of a negative number

is the same as the addition of an inverse when he was given the first problem of the far transfer task [ 3 - (-4)= ]. He asked, "Oh. Minus. . . they'll be going the same way all the time, or not? I need a hint." Using the number line as a reference with this particular problem, Sid's reasoning was correct. However the researcher's request for clarification of his comment appeared to move Sid to a different process, making the three a negative number and then adding the inverse of -4. Sid explained "that would be minused and the other would be back from that... that would be 1". This process was restated later during the hinting process as Sid commented that he could answer the problem by "inversed -4 to 4... minused it by 3... because it says -3." Sid's request for a hint is another example of unelicited metacognitive data in that it showed his awareness of his need for further assistance.

## 4.3 ACHIEVING VERSUS NON-ACHIEVING CHARACTERISTICS

The research question "Are there qualitative differences in the learning, maintenance and transfer processes of achieving versus non-achieving students?", was addressed in Step 5 of the data analysis. The analysis was completed first by charting, and then by comparing the reduced data. Although there were several observed trends, this method most clearly revealed one characteristic qualitative difference in the task approach between achievers and nonachievers: the use of verbal versus nonverbal communication.

Verbal versus nonverbal communication appeared to distinguish achievers from non-achievers in situations where either experienced difficulty during completion of tasks. The achievers appeared to be more comfortable with verbal communication, and the non-achievers appeared to be more comfortable with nonverbal communication once a difficulty was encountered. These different communicative preferences required the researcher, in order to assist the students as they worked, to adjust her presentation by introducing a new prompt, re-explaining a prompt, reviewing previous prompts, or by discontinuing testing. The crucial point is that the student, through his or her communication, influenced the researcher's behaviour and thus the type of interaction.

A previously mentioned example demonstrates a typical use of verbal communication by an achiever. William could not answer the question on rule generation during the learning metacognitive data collection. As part of the researcher's assistance to help him discover the rule, she suggested to William that he could ask questions to obtain assistance in discovering the concept. William's question was "What is the concept?" This response displayed a very sophisticated use of language and humour as a coping strategy. The researcher acknowledged his humour by laughing with him before continuing questioning.

On the other hand Zo, another achiever, appeared to utilize verbal communication to convey her unwillingness to take risks and her lack of confidence. She would question, interrupt the examiner, request hints, and display her need for encouragement by making

comments such as, "I'm dumb." The researcher responded to her comments by offering verbal encouragement and support.

Zo and William's verbal behaviours contrasted with Kenneth, Sid, Carol, and Mary, all non-achievers, who appeared to rely more on nonverbal communication when they encountered problems. Kenneth and Sid demonstrated nonverbal behaviour throughout all three sessions while Mary used nonverbal behaviour only during the far transfer task and relied on verbal expression in other tasks.

Even though Carol was passive and non-communicative at the beginning of the first session, she participated verbally during the session. However, during the near transfer task, the first task in which the hinting procedure had to be initiated, she made some nonverbal responses. She interacted by nodding, making little eye contact, not responding, shaking her head, or making a written response when asked if she would like another hint. While this behaviour was not as noticeable during the far transfer task, nonverbal expressions remained dominant over verbal offerings.

Sid would not make eye contact; he would tilt his head towards the ceiling, sit perpendicular to the table away from the examiner, rock on his chair, and look to the side of the room. These reactions appeared to express his attitude or his impatience with the examiner's explanations or unwelcome questions. It was necessary for the researcher to discuss the importance of the questions, and to ask Sid for his permission to continue questioning.

Kenneth spent some time glancing at the clock, looking at the ceiling, and playing with his pen. Kenneth's nonverbal communication was effective because it forced the examiner to repeat or re-explain questions, or to continue with the hinting procedure. During the far transfer task, Kenneth's unresponsiveness was demonstrated by turning his body away from the researcher. At this point, his testing was discontinued because the researcher felt that Kenneth might walk out, and this would affect his willingness to participate in future sessions.

At the beginning of the far transfer items, Mary felt comfortable to respond with a written response after each hint. Mary's behaviour changed after problem 5 when she was experiencing difficulty with the tasks; she became less verbally responsive and wouldn't answer as readily. Mary would shrug, play with the pen, shake and nod her head and her body would become tense when the number line was retrieved. At one point at the end of the hinting procedure for problem 10, Mary had not responded to several hints. The examiner offered encouragement saying she was "doing fine" and that she should not lose confidence in herself. Mary nodded agreement and answered the next problem without any hints.

In summary, verbal versus nonverbal communication was the only apparent characteristic which differentiated the achievers and non-achievers in this study. In general, differences and similiarities in efficient problem solving characteristics did not correspond to achiever and non-achiever categorization but were trends which crossed these categories.

## 4.4 EFFICIENT VERSUS INEFFICIENT CHARACTERISTICS

Exploration of research question 4, "Are there qualitative differences in the learning, maintenance and transfer processes of achieving versus non-achieving students?" revealed another criterion which was more appropriate for describing individual differences: efficient versus inefficient characteristics.

For the purposes of this study, efficiency was determined by the extent of assistance required by students in order to problem solve. A student was considered to be efficient if he or she was able to use strategies which assisted problem solving without requiring instruction from the researcher. Individuals in both achiever and non-achiever classifications displayed efficient and inefficient characteristics during the tasks.

The three major characteristics which appeared to be paramount in distinguishing efficient from inefficient problem solving processes were language usage, questioning techniques, and risk taking behaviours.

### 4.4.1 LANGUAGE USAGE

The weak language abilities of non-achievers Carol, Sid, and Kenneth appeared to be one area which might cause them some difficulty. They tended to misunderstand questions (Examiner: " What did you think of today?" Kenneth: "Adding negative numbers"), confuse language usage (Sid: " higher than zero" for greater than zero), or have difficulty with word usage (Carol, at one point,

referred to people having to "figure out theirselves"). The other non-achiever, Mary, had language ability which appeared to be adequate, although at one time, she questioned the meaning of "rule."

Despite their weak language abilities, Carol and Sid applied the algebraic vocabulary that was introduced to assist them in problem solving. During the far transfer task, Carol did not appear to understand the meaning of "inverse" and asked the examiner for an explanation of its meaning which the examiner supplied by substituting the word "opposite." Carol was able to solve the problem after Hint 4, and solved the next three problems without assistance. This demonstrated that her questioning of the term "inverse" had assisted her.

An example of how Sid used language for problem solving was demonstrated by the change in his language usage during the far transfer. Initially, Sid continued to have some difficulty with vocabulary ("plain one" for positive one) but by problem 6, he was using the correct terminology of "inverse" to assist his problem solving.

Throughout all the tasks, Kenneth's language ability appeared to be weaker than that of Carol and Sid, and his difficulty with receptive and expressive language may have contributed to his failure to finish the far transfer task. However, during this task the examiner did misunderstand his responses and questioned Kenneth in a way which may have misled him.

Language usage appeared to serve another purpose during the study. Throughout most of the tasks, Zo's language facility appeared to fulfill emotional needs rather than to assist her in thinking. There was a change after problem 9 of the far transfer task which could have been the result of the researcher's prompt to "talk out loud to help her thoughts." Zo did not appear to follow this suggestion immediately; however, for the last two of three problems, she read the problem with the inverse substituted. For example in problem 19, [ -13 - (-1) = ], she read the question aloud, " Negative 13 add 1," and then wrote "-12." Zo was able to solve the last problem quickly and confidently by using supportive self-talk.

Carol made similar use of a talk aloud technique during the first of her last three far transfer problems. Carol subvocalized problem 2 [ - 5 - (-2) = ] as " Negative 5 takeaway negative 2 is 2. Negative 3." This subvocalization appeared to be sufficient for internalization since she did not use this procedure for the remaining two problems.

William's language ability was a strength for him. William was able to solve the learning task's first problem without the hinting procedure being initiated. He read the problem as " minus 5 plus minus 3 equals minus 8." When the researcher corrected his use of "minus", William was able to use the correct terminology "negative" when reading subsequent problems.

In summary, language usage varied and did not reflect a student's verbal or nonverbal communicative preference.

Non-achievers who preferred nonverbal communication still used language for problem solving. Such usage included questioning, using vocabulary introduced through interaction, and talk aloud techniques.

### 4.4.2 QUESTIONING TECHNIQUES

Questioning was an integral component of the interactive diagnosis process because it allowed any student who was having difficulty understanding, or who needed positive reinforcement, the opportunity to ask questions. This was particularly important for non-achievers such as Mary, Carol and Sid, who were able to verify meanings of words or concepts. Such verification would have been impossible if the established guidelines of standardized testing had been used. An example of such an interaction occurred during the far transfer task when Sid pointed to the -4 and +4 on the number line and asked "The inverse is this to that?" This verification allowed him to continue problem solving.

William did not have to use questioning for problem solving. As previously mentioned, William was given the opportunity to ask questions during the learning metacognitive data collection. He asked only one direct question "What's the concept?" which appeared to be tongue in cheek. His lack of inquiry could have indicated either that he does not use questioning as a learning strategy or that the task did not inspire him to question.

Zo asked questions or made comments before she attempted any problem solving. Her comments were based on the theme " I keep on making mistakes", which necessitated an offer of encouragement by the researcher. The type of questioning varied: procedural, clarification or request for hints. However, she did not appear to utilize the information contained in the researcher's answer and would even ask the same question twice within a short period of time. Zo did not always follow this apparent pattern of questioning for continual reinforcement. Changes in her questioning pattern seemed to signal a step in the internalization process. Such changes appeared at two points during the sessions: at the beginning of the near transfer task, and during the far transfer task. When given her first near transfer problem, Zo attempted to apply her rule from the learning task without asking any questions. Later she attempted to ask questions which would assist her in problem solving. An example is her question after hint 1, " Does that mean we can't add this negative if it's positive and negative?" The change in type of questions demonstrated an increasing confidence which eventually resulted in her interrupting the researcher to generate a rule: " Oh, I know, you need the number to add. You have to find the number to add to this to equal 8." Her further questioning at this stage seemed to correspond with a growing confidence in her reasoning. Even though Zo's rule was task specific and would not transfer to another task, she articulated it without any questioning or prompting from the researcher.

During the far transfer task, Zo reverted to her previous questioning pattern and her inconsistency in problem solving. Her questioning appeared to change after Problem 9; during a lengthy re-explanation by the examiner, she did not interrupt or ask questions. Zo nodded agreement to the researcher's review of the two steps in the far transfer tasks, to the suggestion that she attempt another problem, and to the suggestion that she verbalize while problem solving. Zo's silence appeared to signal a step in the internalization process. Even though she asked, "I have to use the inverse for this one right?". . . "Do I add them?", her initial problem solving improved, as demonstrated in her correct solution to problem 10.

A change in questioning also occurred with Kenneth and Sid. During the introductory session, learning task and near transfer task, Kenneth's questions after hints or instructions from the researcher were appropriate for his problem solving strengths. Kenneth requested use of the marble and integer line for problem solving; this could indicate that he is more comfortable manipulating objects than problem solving with hints, and this preference could be related to his weak receptive language abilities. However, even at the beginning of the far transfer task, Kenneth became unresponsive and would not question, nor would he respond to the researcher's questions concerning the need for another hint. The change in Kenneth's questioning might have been a result of the difficulty of the task. Whatever the reason,

Kenneth's change in questioning indicated a change in his task approach.

Sid was another non-achieving student who changed his questioning strategy during the solving of the first problem of the near transfer task (see Appendix C). Sid actually solved the first problem after Hint 2 and then again after Hint 6, but he requested all ten hints. Sid's questioning for problem solving continued throughout the far transfer task; he played a very active role by questioning when he didn't understand.

Questioning was an important facet of dynamic assessment since it allowed the student the opportunity to influence the type of interaction established with the researcher. In the present study, purposes of student questioning techniques varied since students asked questions when they misunderstood word meanings or needed positive reinforcement. During the three sessions changes were noted in students' questioning which appeared to reflect changes in the student's problem solving strategies.

### 4.4.3 RISK TAKING

The nature of interactive diagnosis allows speculation into another factor which could affect learning, risk taking. Risk taking is defined here as an attempt to problem solve without hints; cautious behavior is defined as a request for a hint without attempting to problem solve. In this study, risk taking could favour students who prefer nonverbal communication since a written

response is considered an example of risk taking behaviour. A verbal communicative preference for asking questions before writing an answer is not considered risk taking behaviour.

Risk taking and cautious behaviour contrasted and appeared to reflect a student's personality and/or level of self-confidence. This behaviour seemed to affect a student's ability to problem solve; students who took risks appeared to be more efficient. However, it is difficult to determine if this was a personality trait or if it reflected a student's knowledge base.

Individual differences were noted in the following cases: Zo's continual request for hints before making a response; Carol's and Mary's attempts at problem solving after each hint; and Sid's change in levels of risk taking during the study. During the study, risk taking was not evident for William and Kenneth. This may be the result of the nature of the tasks: the tasks did not challenge William, and the far transfer task was too difficult for Kenneth.

As previously discussed, Zo experienced difficulty in problem solving without questioning and requesting hints. In contrast, when the researcher asked Carol if she would like another hint, Carol tended to answer the problem with a written response before the hint could be given.

In Sid's case, there was a change in his risk taking from the learning task to the near transfer task. During the learning task Sid was very active. He would usually respond to hints by asking questions and then moving the marble to assist himself to problem solve. However, during the near transfer Sid became quite cautious

and requested all the hints. Sid's behaviour reverted to his original active role during the far transfer task.

In the present study, students could request hints to assist their problem solving. Individual differences were noted in students who requested hints, and those who attempted to solve without any hints. This later behaviour was defined as risk taking behaviour and, in some cases, there were changes in the levels of risk taking. Risk taking, as a result of personality characteristics, or as a reaction to a particular context, appears to affect problem solving efficiency.

In addition, there were minor characteristics which appeared to affect problem solving. These were demonstrated by students during the internalization processes but were considered to be secondary to the three major characteristics. The minor characteristics were rate of response; utilization of number line for problem solving; visualization of number line for problem solving; using strategies to compensate for weak basic skills; and self-corrections.

## 4.5 METACOGNITIVE QUESTIONING

### 4.5.1 INTRODUCTION

Metacognitive data was collected after the learning, maintenance, and transfer tasks. Although the zone of proximal development research surveyed for the present study does not include

metacognitive components, they were included here in order to shed some insight into the students' self-perceptions of problem solving.

Similar questions following the same sequence were used after each of the tasks. Students were asked to determine how they perceived their problem solving (metacognitive question 1, see Appendices B, C, and D), whether they recognized the difference in problems or solved them differently (metacognitive question 2, see Appendices B, C, and D), and whether they could generalize a rule for each type of problem (metacognitive question 3, see Appendices B, C, and D).

There were two trends observed during the metacognitive data collection. Both trends seemed to relate to a differentiation between achievers and non-achievers. First, three of four non-achievers did not wish to answer all the questions. For example, Sid, when asked to explain how he problem solved, became quite defensive and replied "I don't know... first I minused and then I plused... I'm not a brain." Later, Sid attempted to explain that he did not like the researcher's questions since he did not normally ask such questions of others.

Second, two of four non-achievers tended to misunderstand the questioning. In particular, they appeared not to understand the concept of rule, and asked questions to verify its meaning. After the learning task, and when they were first asked to generate a rule, Carol and Mary asked clarifying questions to determine the meaning of "rule" before they attempted to answer. For example, Carol asked, "Like how (do) you say it?" When the examiner began

to explain, Carol interrupted to say, " Minus 8 plus minus 5 equals minus 13." The two achievers, Zo and William, answered all the questions and appeared to understand the questioning and the concept of rule.

The non-achievers' reluctance to answer questions and tendency to misunderstand questions must be considered when interpreting the data. These characteristics could be considered data in themselves, but they might also have affected the value of the data collected as it applies to Giorgi's phenomenologocal method for data analysis. Since language is the data for analysis, miscommunication can result in data which is more reflective of the breakdown in communication than of metacognitive understanding.

The metacognitive data can also be considered an individual matrix similiar to the study of the learning, maintenance, and transfer processes. For example, William was efficient at problem solving but this efficiency did not translate into the ability to articulate a rule, except during the maintenance data collection as previously discussed. William's efficiency in problem solving could have been a result of his sense of mathematical concepts or due to reading the encyclopedia. During the sessions, the tasks did not appear to challenge William, as the prompting procedure did not have to be initiated until the far transfer task. However, he was motivated by the tasks to read the encyclopedia even though he did not respond to the task methodology during the sessions. Still, he did not articulate an acceptable rule. One previously mentioned

explanation for his difficulty generating a rule is that the verbal rule generation process is independent of algebraic problem solving.

### 4.5.2 STUDENTS' PERCEPTION OF GENERATING ALGEBRAIC RULES

The data selected for presentation was collected from responses to the question "If you wanted to explain how you solved these problems using a rule, what would it be?" (metacognitive question 3, see Appendices B, C, and D). The same question was presented after each task. It closely followed the demonstration of behaviours that indicated an understanding of algebraic rules used in the tasks and, therefore, could have influenced performance on subsequent tasks.

At some point during the metacognitive learning questions, each student responded by not attempting to generate a rule. The manner in which they expressed themselves varied: "Can't think of a rule (William);" "Can't explain (Carol);" "No ( Mary);" "Don't know (Kenneth)."

When the students did respond, they generally appeared to confuse the process of problem solving with a rule for problem solving; they would explain the method by which they solved problems rather than supply a rule. The reverse also occured. For example, Mary generated a rule when asked for an explanation of the process of problem solving.

An example of this confusion occurred during the near transfer task when William responded, "You subtract... When you have one negative, and then you get the answer." This could be categorized

as an answer to the problem since his explanation suited the specific task of adding a positive and a negative number when the positive addend is larger than the negative addend.

Kenneth provided another example of a process type response. The only time Kenneth responded to metacognitive question 3 was after the learning task; he would not attempt to generate a rule after the remaining tasks. Kenneth's initial answer referred to the process involved in problem solving: "I didn't use the number line." When asked to expand further, Kenneth responded with a literal interpretation of the process: "You count in your head... and figure out the number... write down the answer.... and the negative."

Mary was not as efficient at problem solving as William and Carol. However, she appeared able to generate rules even when she didn't understand the meaning of the word "rule". When asked "Can you tell me how you solved these problems?" (learning metacognitive question 1, see Appendix B), Mary did not answer at the specific level of problem solving as did the other students. For example, William had said, "Just negative 5 plus negative 3 equals negative 8." Mary generated a rule which explained all the problems: "Okay. You add there two negative numbers... And you come up with a negative number." This answer would have been considered adequate for metacognitive question 3 which requested a rule. When asked this question, Mary's first response was that she didn't know the answer. Further questioning revealed that she didn't understand the concept of the word rule. After the meaning was explained, Mary

continued to have difficulty articulating a rule. Further questioning resulted in Mary restating her response from question 1. In fact, Mary came closer to generating a rule for the far transfer task than anyone. Initially, she replied that she couldn't supply a rule and then she responded, " Adding towards the positive." Mary had successfully generated a process which incorporated the number line. Even though this is not a general rule, Mary's rule was the only one which could be used for all the far transfer problems.

The data analysis demonstrated that the rule generation question is one aspect of metacognitive data collection which could have affected the maintenance and transfer problem solving tasks. Zo's case is the only example of a negative influence of rule generation on problem solving. A negative effect was demonstrated during the far transfer task, as the rule she had spontaneously generated during the near transfer task appeared to interfere with her future problem solving rather than to assist her. This interference was the result of the type of rule that Zo had articulated; the rule was very task specific and did not transfer to another task. However, she seemed compelled to cling to the rule. The researcher encouraged Zo to adapt but, even though she appeared to be aware that the near transfer rule would not help her problem solve, she would not relinquish the ineffective rule and generate another one. Zo's inflexibility was evident as she continued to attempt to problem solve using an ineffective rule which interfered in her problem solving, even after the researcher suggested to her that another rule would be more helpful.

## 4.6 SUMMARY

A cross-case analysis of verbal and nonverbal protocol data gathered from six Indian achieving and non-achieving Grade Seven students, and reduced through use of a technique developed by Giorgi (1975, 1979, 1985b), yielded information regarding the subjects' internalization processes of algebraic concepts. Zone of proximal development methodology, which was employed in the study, permitted the researcher to investigate processes used by the students during learning, maintenance, and near and far transfer tasks. While verbal and nonverbal communication styles appeared to distinguish achieving from non-achieving students, those same traits did not seem to affect efficiency in problem solving as observed during the present study. Other characteristics such as language usage, questioning techniques, and risk taking were the traits which most clearly affected the students' problem solving skills.

Formal metacognitive data proved hard to collect. This may be attributed to the reluctance of some students to participate in the questioning, and to the difficulty other students experienced in understanding the questions. All students had difficulty at some stage of the study in generating a rule to explain how they had solved the problems.

# CHAPTER FIVE

## 5.1 SUMMARY OF TOPICAL RESEARCH QUESTIONS

The purpose of this study was to use an alternate pscyhoeducational assessment method to examine the internalization processes of Indian students in an academic domain. Alternate methodology was necessary because current research methods and learning potential assessment techniques are culturally biased. As a result, cultural differences of Native students are often interpreted as learning deficits, and this interpretation prejudices most Native students in the school system.

A cross-case model of reporting the results was employed using information gleaned from verbal and nonverbal protocols, which were obtained from video and audio recordings of three data gathering sessions. The nature of the present research was an in-depth study to identify trends or speculations which could provide a framework for future research into Native education. Although the sample consisted of only six students, the qualitative research paradigm allowed the researcher to explore important issues in Native education, and to suggest the possible contribution of the results of the present study on these issues and to future research.

The zone of proximal development methodology was used to explore the following research questions:

1. Can the zone of proximal development yield diagnostic

information on individuals' learning processes?

2. Can the zone of proximal development yield diagnostic information on individuals' maintenance processes?
3. Can the zone of proximal development yield diagnostic information on individuals' transfer processes?
4. Are there qualitative differences in the learning, maintenance, transfer processes for achieving versus non-achieving students?

To facilitate the discussion, questions 1 to 3 have been combined to read: Can the zone of proximal development yield diagnostic information on individuals' learning, maintenance and transfer processes? Further discussion will focus on qualitative differences between achieving and non-achieving students, and qualitative differences among all the students revealed by the analysis of the verbal and nonverbal protocols.

### 5.1.1 CAN THE ZONE OF PROXIMAL DEVELOPMENT YIELD DIAGNOSTIC INFORMATION ON INDIVIDUALS' LEARNING, MAINTENANCE AND TRANSFER PROCESSES?

In the present study, it was found that zone of proximal development methodology did yield diagnostic information on the individual's learning, maintenance and transfer processes. The dynamic nature of this approach to assessment provided descriptors of the students as learners at different stages of their learning. It gave the researcher the opportunity to follow each student

through tasks. An error was considered to be an opportunity to discover some information on the cause of the error, as well as to offer a hint which might lead the student to a better understanding of the concept. Dynamic assessment also allowed examination of the students' affective reactions while they were problem solving. This, in turn, gave the researcher insight into personality factors that may have affected the completion of tasks.

Through dynamic assessment, the assessor adapted to the student's mode of answering which gave more information about the students as learners and their individual problem solving styles than a standardized static measure would have given.

The teaching-learning nature of dynamic assessment and the interactive assessment techniques also provided a method by which the researcher could observe changes in students as they learned. As stated by Gagne (1968): "One of the most prominent characteristics of human behaviour is the quality of change (p. 177)." A description of the individual processes of change gave important information that could not be obtained by static measures.

In the remainder of this chapter, the diagnostic information uncovered by the zone's methodology will be used to discuss the qualitative differences between achieving and non-achieving students (Section 5.12). It will also be used to present more detailed observations regarding similarities and differences between individual students (Sections 5.2.1 through 5.2.6).

### 5.1.2 ARE THERE QUALITATIVE DIFFERENCES IN THE LEARNING, MAINTENANCE, TRANSFER PROCESSES FOR ACHIEVING VERSUS NON-ACHIEVING STUDENTS?

This study examined the learning, maintenance, and transfer processes of achieving versus non-achieving students. The diagnostic information for each student was used as a basis for discussing a comparison. Categorization of the sample into achievers and non-achievers was based on CTBS grade equivalent scores, and Grade 7 Mathematics marks on the First Report Card. The results of this study indicated that the CTBS test scores and classroom evaluation in Mathematics may not be indicative of efficiency in problem solving and hence, may be ineffective as predictors of learning potential of Native students. This conclusion was the result of the observed efficient problem solving strategies displayed by some of the non-achievers and the observed inefficient strategies displayed by an achiever.

These results lend support to Brown and Ferrara (1985), who found that standardized test results such as IQ scores failed to predict almost fifty percent of children's learning and transfer profiles. In the present study, the categories separating achievers and non-achievers did not predict efficiency during task performance. For example, Zo, an achiever, completed the far transfer task by having to work through more problem cards than any student other than Kenneth, a non-achiever, who did not finish the task.

There are four factors which may contribute to the ineffectiveness of the achiever and non-achiever categorization to predict efficiency in problem solving. First, there is a cultural bias in standardized testing which has been well discussed in the literature (Bradley, 1984; Rampaul et al., 1984; Seyfort et al., 1980). The static nature of standardized testing could also contribute to this bias because it assumes that past learning can predict potential for future learning. Standardized testing, therefore, inadequately reflects culturally different students' potential for learning (Campione et al., 1982; Feuerstein, 1980).

Second, although test scores might adequately reflect the learned skills expressed under controlled conditions, inadequate or culturally biased instruction, culturally biased mathematics curriculum, English as a Second Language (ESL) and English as a Second Dialect (ESD) preference, and socio-cultural factors may account for the under- achievement of some students.

Third, standardized testing does not provide for interactions between students and examiners. Dynamic assessment's interactive or cooperative method might reduce the discrepancy in test scores, since the student has the opportunity to affect the type of interaction with the researcher. During this study, the non-achievers tended to have very weak basic skills and weak Standard English language abilities. However, despite these weaknesses, the collaborative design of dynamic assessment allowed the students to use their own strategies, such as questioning, to verify procedures and to assist in problem solving. This cooperative

approach might be a better method for assessing learning potential of Native students since cooperation is a part of traditional Native society and a successful method of instruction in the classroom (Boseker & Gordon, 1983; Dumont, 1972).

Fourth, the categorization may have worked against an achiever, Zo. The results indicate that her problem solving lacked a pattern, and this lack could point to an interference in her thinking. Possible reasons for this interference are discussed under section 5.2.4 "Effects of risk taking on problem solving".

In summary, there were qualitative differences in learning between subjects, but those qualitative differences did not follow a pattern of achievement versus non-achievement as delineated by CTBS and classroom evaluation. Therefore, discussion of the results from this study focuses on the qualitative differences among all the students rather on differences between the achievers and the non-achievers.

## 5.2 DISCUSSION OF TRENDS

The discussion of the results of the present study will focus on trends revealed through the data analysis. The quantity of data does not allow speculation into all facets of this study, but there will be an attempt to discuss identified trends, thereby allowing an examination of relevant issues in Native education.

### 5.2.1 PREFERENCE FOR NONVERBAL COMMUNICATION DOES NOT AFFECT PROBLEM SOLVING STRATEGIES

Verbal versus nonverbal communication was the only characteristic which corresponded with the achiever versus non-achiever categorization. That is, the verbal students in the group tended to be the achievers and the nonverbal, the non-achievers. Greenbaum and Greenbaum (1983) characterize nonverbal communication as "silent or invisible language" which may cause learning interference for Native children within the classroom context (p. 17). In this study, the preferred means of communication, verbal or nonverbal, did not appear to affect efficiency in problem solving.

Zone of proximal development methodology delineates the collaborative role of the teacher and the student (Wertsch and Rogoff, 1984). Interaction is the key to teaching; since there is an instructional component built into zone of proximal development and dynamic assessment methodology, interaction is also the key to dynamic assessment. As stated by Donaldson (1978): "The essence of the teacher's art lies in deciding what help is needed in any given instance and how this help may best be offered ( p. 101)." The Laboratory of Comparative Human Cognition (1983) has explained that "the model of the teacher is to be a model of an adaptive expert (p. 53)."

During this study, it was necessary for the researcher to adapt to either verbal or nonverbal communicative preference in order to

interact and assist the students in problem solving. In other words, the instructional component of dynamic assessment's methodology and the qualitative research design allowed the researcher to adopt an interactive teacher's role rather than a traditional non-interactive assessor's role. Therefore, a preference for nonverbal communication did not prevent students from receiving assistance in their problem solving. If students preferred nonverbal communication, the results indicated that they could still use language for problem solving. The next section of this paper addresses the ways in which the students used language as a tool to facilitate their learning.

### 5.2.2 THE CONNECTION OF THINKING AND LANGUAGE WITH LEARNING POTENTIAL ASSESSMENT

Results of this study indicated that Kenneth, a non-achiever, had weak language skills that hindered his ability to complete tasks. However, Sid and Carol, also non-achievers with weak language skills, were able to complete the tasks using the introduced algebraic vocabulary for assistance. Zone of proximal development methodology allows examination of the processes by which newly introduced vocabulary, such as algebraic vocabulary, is used for thinking. As stated by Vygotsky (1986):

> Until recently the student of concept formation was handicapped by the lack of experimental method that would allow him to observe the inner dynamics of the

> process. . . . Learning to direct one's own mental processes with the aid of words or signs is an integral part of the process of concept formation. The ability to regulate one's actions by using auxiliary means reaches its full development only in adolescence (pp 96 - 106 ).

Sociolinguists believe that there are social foundations for language and that the culturally different students' language reflects their cultural difference rather than a deficiency. Labov (1972) states: "Language is a form of social behavior; children raised in isolation do not use language; it is used by humans beings in a social context, communicating their needs, ideas, and emotions to one another" (p. 183).

The school system reflects the mainstream society's use of Standard English communication skills, which are necessary for school achievement. Parry (1982) explains that "such assumptions are ethnocentric in that communicative skills are defined as the particular language skills measured by the school (p. 21)." ESL or ESD Indian students are at a disadvantage in the school system because their language differences are interpreted as deficits and alternate programming is established on the basis of this assumed deficit. This alternate programming has tended to follow the "deficit model of remediation." Labov (1972) agrees: "Myth of verbal deprivation is dangerous because it diverts attention from

real defects of our educational system to imaginary defects of the child" (p.23).

In terms of the present study, Sid and Carol were both attending the Resource Room for modified Math programming. However, Carol and Sid were able to use the language of the school, or the introduced algebraic vocabulary, as a tool to assist their thinking. Kenneth's language abilities were too weak to allow him to work through the tasks. In a school context, zone of proximal development methodology allows a further assessment of the learning potential differences among culturally different students. The interactive nature of the assessment offers the possibility of introducing new vocabulary and examining the students' demonstration of the new terms for problem solving.

### 5.2.3 TOP DOWN APPROACH IN TEACHING ALGEBRA

All of the non-achievers had difficulty with basic skills such as adding and subtracting at the automatic level, substituting numbers and distinguishing operation signs. Three of the four non-achievers were in the Resource Room for remedial mathematics, and therefore, not included in the Grade Seven Math programme.

In most schools in Saskatchewan, decisions to allow entry into Algebra courses are based on students' CTBS marks and on their achievement in the classroom as designated by report card marks. Weak basic skills affect CTBS scores and report card marks; however, these weaknesses could be the result of culturally biased

instruction and curriculum, ESL/ESD influences or socio-cultural factors. As such, the current criteria may not reflect a deficiency which would prevent students learning algebra, which is primarily a process of thinking.

A similar argument has been presented by Moll (in press) in discussing the underestimation of reading or writing abilities by ESL students: ". . . (The school system assumes) that they cannot engage in advanced English literacy activities until they master lower order basic skills, such as decoding. The intellectual level of lessons, therefore, is constrainted accordingly" (p. 6).

Vygotsky (1986) suggests that teaching higher thinking skills may actually assist students in learning basic skills. This premise may be a result of Vygotsky's conceptualization of development, which included quantitative and qualitative shifts. Vygotsky theorized that quantitative or evolutionary shifts are a result of biological or innate abilities in humans; these form "elementary mental functions." Qualitative or revolutionary shifts are a result of mediated, internalized interactions and account for "higher mental functions" (Vygotsky, 1978). As stated by Vygotsky (1986):

> Algebraic concepts represent abstractions and generalizations of certain aspects of numbers, not objects, and thus signify a new departure - a new, higher plane of thought.
>
> The new, high concepts, in turn, transform the meaning of the lower. The adolescent who has mastered

> algebraic concepts has gained a vantage point from which he sees concepts of arithmetic in a broader perspective (p.202).

Vygotsky's conceptualization of the effect of higher mental functions on lower mental functions could be applied through a top down approach in teaching Algebra in the school system. That is to say, students with weak basic skills in Math could be enrolled in Algebra classes. Instruction in algebraic concepts may assist them in understanding mathematical concepts and, in turn, improve their basic skills mastery.

### 5.2.4 EFFECTS OF RISK TAKING ON PROBLEM SOLVING

The nature of the interactive diagnosis in this study allowed speculation into how risk taking may affect problem solving. Analysis of the protocols distinguished differences between individual problem solving strategies. These may reflect an individual's personality, attitude, or response in a particular context. In the present study, risk taking was not solely related to students' school achievement levels. Zo, an achiever, was a non-risking student while Carol, a non-achiever was a risk taker.

There could be several reasons for Zo's lack of risk taking. First, her perception of her status as an achiever could have resulted in her cautious behaviour. Research indicates that the degree of risk taking is dependent on past experiences, fear of failure, ability to predict success, perception of others'

perceptions, uncertainty, context, and, in case of mathematics, gender (Bell & Margolis, 1985; Linn, 1985; Sisson, 1985).

Second, the nature of interactive diagnosis may favour a different type of risk taking than Zo's personality would allow. Zo depended on social acknowledgment throughout all the sessions; and this dependency may have reflected her personality, which had an "external locus of control." In a school context, an external locus of control personality believes that school successes are determined by extrinsic factors, such as teachers (Bendall, Tollefson, & Fine, 1980). Zo's verification requests could also be a strategy which has proven more effective for her in a different context, such as school, than it did during this study. Zo might also be more comfortable being part of a group than being in a one-to-one testing situation.

Third, her lack of risk taking could be attributed to "math aversion" or "math anxiety" which has been documented in the research in relation to female gender (Stodolsky, 1985; Tobias & Weissbrod, 1980).

Whatever the reason(s) behind Zo's behavior, risk taking appears to be important to life efficiency, and Zo's cautious behaviour affected her ability to problem solve effectively.

Though Carol was a non-achiever, she had the confidence that one would expect of an achiever during the three sessions. Carol's confidence was demonstrated by refusing hints and wanting to solve the problems independently. In fact, Zo's and Carol's personalities

could be considered opposite since Zo appeared to have an external locus of control and Carol an internal locus of control.

### 5.2.5 ROLE OF STUDENTS' QUESTIONING IN THE INTERACTIVE ASSESSMENT PROCESS

Student generated questioning in interactive diagnosis can simulate a teaching-learning situation. The information gleaned from analyzing the questioning process can be transferred to an instructional situation.

The type, level, and frequency of questions were primary reasons that the phenomenological method of data analysis was undertaken instead of the proposed quantitative mapping. Although the students were encouraged to ask and answer questions, the extent and the scope to which they questioned and influenced the interaction was not expected. The number and quality of student-generated questions may be attributed to the fact that most of the students knew the researcher and were comfortable with her. However, asking questions was an important method by which the students' could control or affect the interaction as they completed the tasks. The type of questions varied and appeared to reflect a student's problem solving strategies and personality, as well as signalling changes in comprehension during different sessions and within sessions. Questions were examined as to the purposes they served in the interactive learning process. A more detailed

linguistic analysis was beyond the parameters of the research questions.

Zone of proximal development methodology is a teaching-learning situation. In terms of the zone of proximal development, "development is more appropriately viewed as changes in responsibility for certain steps " (Griffin & Cole, 1984, p.47). With three students, Zo, Sid, and Kenneth, the change in style of questioning appeared to signal a shift of responsibility for learning from the researcher to the student. Sid increased his use of questioning when he seemed to become cautious and afraid to answer incorrectly. Zo's change of level of questions and her use of more questions appeared to reflect her increased confidence. Kenneth's decreased questioning may have indicated that he wanted to withdraw from the testing situation. Although each of the motives behind the use or lack of use of questioning was different, the common element was a transfer of responsibility from the researcher to the student. Kenneth, Sid, and Zo began to control their learning by controlling their participation.

In the past, research on zone of proximal development methodology emphasized the instructional application. Several researchers have attempted to create structure in the form of models for reading instruction (Laboratory of Comparative Human Cognition, 1983; Langer & Applebee, 1985; Palincsar & Brown, 1984; Rogoff, 1984). These studies have common characteristics: interaction between more a capable person and a learner; socially relevant activity; guiding of the transfer; and transfer of responsibility.

In the present study, the learning, maintenance and transfer tasks that occurred during the three separate sessions allowed an examination of the questioning strategies of students and, in particular, of any changes that took place in those strategies. Student generated questions can be considered important in the interaction between teachers and students. When students can control the interaction, they can affect what they learn.

### 5.2.6 EFFECTS OF RETROSPECTIVE VERBALIZATIONS

As previously mentioned, the value of the formally gathered metacognitive data decreased because the nonachievers were reluctant to answer and tended to misunderstand questions, resulting in sparse and off-target verbal protocol data. These factors affected the amount of specific information which could be gleaned through Giorgi's phenomenololgical method for data analysis. The utilization of the nonscheduled standardized interview format after each task may have affected the verbal reports of problem solving as well. The students' reactions to the metacognitive questions appeared to be somewhat negative and may have affected subsequent task performance. Generally, the students seemed to be reluctant to answer all the questions, had difficulty understanding the purpose of the questions, and found the vocabulary used by the researcher difficult to comprehend.

The metacognitive data was collected by a procedure called restrospective verbalization which probes students after the

"completion of the task-induced processes" (Ericsson & Simon, 1980, p. 220). Ericsson & Simon (1980) discuss some effects associated with retrospective verbalization on subsequent task behavior.

> The first is that if the subjects do not normally organize what they learn in these experiments in verbalizable concepts and general principles, then verbalization forces them to generate such concepts and principles from whatever information is currently available to them. (p.234)

The effect of retrospective verbalization on subsequent tasks could account for the interference of Zo's ineffective near transfer rule during the far transfer problem solving (see Appendix D). During learning metacognitive data collection, Zo was asked to generate a rule to explain her problem solving (see Appendix B). Zo may have been led into thinking about and verbalizing rules when she was not ready. During the near transfer problem solving, she spontaneously generated a specific rule without any request from the researcher. Her rule was effective for the near transfer task, but was not transferrable to the far transfer because of its specificity. During the far transfer task, Zo had difficulty relinquishing her near transfer rule, which made it difficult for her to adapt to the far transfer task. If rule generation had not been requested until Zo had the opportunity to work on more problems and reflect on her learning, she may have been less rigid in her application of the rule.

This demonstrated effect on retrospective verbalization appears to be a result of Zo's personality, or her lack of confidence in this context. As a result of learning metacognitive questioning, it seems that Zo decided that rule making was actually an important task for the study, and therefore independently created a rule during near transfer problem solving. The researcher reinforced the rule as being correct and Zo would not adapt during the next task by relinquishing the rule, even when encouraged to do so by the researcher.

Inclusion of one final metacognitive interview at the conclusion of the data gathering phase, rather than repeated use of a similar measure, may have yielded different results. While it would have not have overcome the problems with receptive and expressive language, it may have been less tedious for the students and would have given them more time to incorporate concepts before they were asked to generate rules. However, in the present study informal metacognitive data appeared to yield more information than the formal data collection. Further detailed transcript analysis would permit more in-depth study of spontaneous metacognitive verbalizations.

## 5.3 EDUCATIONAL IMPLICATIONS AND DIRECTIONS FOR ACTION AND FURTHER STUDY

Results of this study suggest several educational implications and directions for additional research and action.

### 5.3.1 EDUCATIONAL IMPLICATIONS

First, zone of proximal development methodology provides a process assessment of students' learning potential in academic domains. This method can uncover learning potential profiles that have been masked by static standardized tests, which reflect only present knowledge and skills. Weak basic skills as a result of cultural differences do not adequately reflect learning potential, and may hinder students' access to entrance into secondary school courses.

Second, even though the present study's focus was on Native education, dynamic assessment is a process assessment which is valuable for all students. Leong (1987) summarizes: "Diagnosis should be a clinical procedure capable of yielding information on the processes and tactics of reasoning, and problem solving" (p. 47)

Third, zone of proximal development methodology may provide assessment which directly assists teachers in designing instructional tactics. Differentiated instructional information such as verbal or nonverbal communication preference, type or amount of student generated strategies, the processes of Standard English language concept formation, questioning strategies, and risk taking can be considered important diagnostic information for programming purposes.

Fourth, sophisticated screening techniques based on dynamic assessment's method of examining learning potential in the domain of Algebra can assist teachers, parents, and students to make informed

educational decisions. Currently used static measures predict school failure or success for Native students because teachers tend not to be cognizant of the limitations of these measures. As stated by Cummins (1986): "professionals involved in assessment (should) become advocates for minority students rather than legitimizing the location of the "problem" in the student" (p. 21).

Fifth, parents', students,' and teachers' expectations towards students' learning potential can affect decisions regarding students' admissions into Algebra courses, and therefore, limit their post- secondary educational choices.

Sixth, administrators, program counsultants, and teachers currently implementing Saskatchewan Department of Education's Common Essential Learnings (C.E.L.s') should be interested in zone of proximal development methodology. C.E.L.s' encourages the "top down" approach to teaching concepts rather than the basic skills approach. Zone of proximal development methodology can give important evaluation information on the efficacy of teaching higher thinking skills to improve students' weak basic skills.

### 5.3.2 DIRECTIONS FOR ACTION AND FURTHER STUDY

First, since more sophisticated assessment techniques are needed to examine learning potential, there should be more research on zone of proximal development methodology or dynamic assessment with students. Research in this area may also lead to zone of

proximal development methods replacing static standardized testing as indicators of learning potential in a school context.

Second, there should be an examination of school practices which screen Native students out of Algebra courses because of their weak basic skills and Standard English language abilities. Cheek (1984a) suggests that in order to increase the participation of Native students in Mathematics, the expectations of students, teachers, parents, and counsellors regarding students' success will have to be raised. She states that "Mathematics is important to these students' futures and they do have the ability to perform successfully in Mathematics" (p. 108). These decisions may increase enrollment and students' success in Algebra courses.

Third, additional research in zone of proximal development methodology would allow the examination of the processes involved in the internalization of mathematical concepts. In the past, zone methodology has been used successfully to examine the linkage of culture and cognition (Gay & Cole, 1967; Saxe & Posner, 1984; Scribner & Cole, 1981). Since culture affects cognition, additional research into the effect of Native culture(s) on the internalization of mathematical concepts is needed in order to guide the development of curriculum and teacher education programs (Bradley, 1984).

Finally, a study is needed to investigate Native students' nonverbal communication and classroom teachers' responses to nonverbal communication. As a result of the interactive nature of dynamic assessment, the present study suggests that nonverbal communication does not adversely affect problem solving strategies

when the instructor responds appropriately. Additional research into the area of teachers' responses to students' nonverbal communication, and the effects of the responses on students' problem solving strategies, will have instructional implications. As stated by Greenbaum and Greenbaum (1983): "Continued research on nonverbal differences and (sociolinguistic) interference would be a fine step towards ameliorating one type of problem Indian children experience in their schools" (p. 30).

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# APPENDICES

# APPENDIX A

## SUMMARY
## OF PRETEST PROCEDURES
## DURING FIRST SESSION

# Appendix A

## Summary Of Pretest Procedures During First Session

All students completed the following tasks:

I. A review of number line
   1. Showing the number cards the examiner said: "What are these figures called?" (numbers)
   2. Holding the concrete number line the examiner said: "What is this?" (number line)
   3. Can you place these numbers on the number line?" Using the correct numerical sequence, the student attached the number cards to the concrete number line.
   4. Using the concrete number line, the student added and subtracted the problems shown below. This was to ensure the student was able to add and subtract using the concrete integer line.

II. A pretest on addition and subtraction
   The student completed the pretest on addition and subtraction shown below. This was a pencil and problem card task similar to learning, maintenance and transfer tasks.

| | |
|---|---|
| 1. 5 + 3 = | 10. 0 + 5 = |
| 2. 10 + 4 = | 11. 17 - 2 = |
| 3. 3 + 8 = | 12. 2 + 3 = |
| 4. 19 - 2 = | 13. 7 + 9 = |
| 5. 15 - 7 = | 14. 11 - 0 = |
| 6. 1 + 4 = | 15. 20 - 3 = |
| 7. 13 + 4 = | 16. 9 + 8 = |
| 8. 8 - 4 = | 17. 11 - 3 = |
| 9. 15 + 1 = | 18. 4 + 15 = |

# APPENDIX B

# SUMMARY OF LEARNING AND MAINTENANCE PROCEDURES

# Appendix B

## Summary Of Learning And Maintenance Procedures

### Sequence of Learning and Maintenence Problems

| | |
|---|---|
| 1. -5 + (-3) = | 7. -6 + (-3) = |
| 2. -8 + (-5) = | 8. -6 + (-6) = |
| 3. -11 + (-3) = | 9. -14 + (-5) = |
| 4. -4 + (-5) = | 10. -2 + (-7) = |
| 5. -9 + (-4) = | 11. -3 + (-8) = |
| 6. -13 + (-5) = | 12. -12 + (-5) = |

"Learning" was the only task of the second session, while maintenance was the first part of the third session. During learning and maintenance, similar but not identical problems were given to the student. The problems were sequenced to vary their level of difficulty as the sums of the problems were less than or greater than ten. The sequence and type of prompts were identical for both sessions.

### Second Session

#### Learning Data

##### Basic Instructions

Giving the student a problem card, the examiner said:

> "I'm going to give you a problem to answer with numbers. Write down the answer."
>
> -5 + (-3) =

1. If the answer was correct, the next problem was given.
2. If no or an incorrect answer was given, a sequence of prompts was followed.

##### Prompt Sequence

The examiner said:

> "I'm going to give a hint. If you can answer with this hint, go ahead. If not, I'll give you another."

1. Demonstrating the concrete integer line, the

examiner said:
"For each positive number we can invent a new number called a negative number. If this number is positive 1, the new number is negative 1. If this number is positive 2, the new number is negative 2."

2. "All the positive numbers are greater than 0 and all the negative numbers are less than 0."
3. "Can you read the problem?" (-5 + (-3) )
4. "What are you to do with -5?" (Add -3)
5. "Can you see the number line in your mind?"
6. "Use the number line" (The examiner gives the student the concrete integer line.)
7. "Can you find -5?"
8. "What are you to do with -5?" (Add -3)
9. "To add -3, you move to the left."
10. "You move three spaces to -8."

The card was turned over and the next one was presented. The same procedure was followed for the next problem. After the student solved the first problem without assistance, the examiner told her or him that the session would be finished when she or he solved three problems in a row without assistance.

### Metacognitive Data

After the third problem was solved without assistance, the problem cards were shown to the student and each student was questioned. As part of the nonacheduled standardized interview format, the following questions were utilized as a general framework:

1. Can you tell me how you solved these problems?
2. Was there a difference in solving the second problem from the first problem?
3. If you wanted to explain how you solved these problems using a rule, what would it be?

## Third Session

### Maintenance Data

#### Basic Instructions

Giving the student a similar but not identical problem as the learning session, the examiner followed the identical process as with the learning data.

$$-2 + (-7) =$$

1. If the answer was correct, the next problem was given.
2. If no or an incorrect answer was given, a sequence of prompts was followed.

Prompt Sequence

The examiner said:

"I'm going to give a hint. If you can answer with this hint, go ahead. If not, I'll give you another."

1. Demonstrating the concrete integer line, the examiner said:
   "For each positive number we can invent a new number called a negative number. If this number is positive 1, the new number is negative 1. If this number is positive 2, the new number is negative 2."
2. "All the positive numbers are greater than 0 and all the negative numbers are less than 0."
3. "Can you read the problem?" (-2 + (-7) )
4. "What are you to do with -2?" (Add -3)
5. "Can you see the number line in your mind?"
6. "Use the number line" (The examiner gives the student the concrete integer line.)
7. "Can you find -2?"
8. "What are you to do with -2?" (Add -7)
9. "To add -7, you move to the left."
10. "You move seven spaces to -9."

The card was turned over and the next one was presented. The same procedure was followed for the next problem. After the student solved the first problem without assistance, the examiner gave the student at least two more problems to ensure the student had maintained what she or he had learned.

Metacognitive Data

After the third problem was solved without assistance, the problems cards were shown to the student and each was asked to explain how she or he solved the problems. To investigage the student's perception of maintenance each was asked:

1. Can you tell me how you solved these problems?
2. Are you familiar with these problems?
3. If you wanted to explain how you solved these problems using a rule, what would it be?

# APPENDIX C

# SUMMARY OF
# NEAR TRANSFER PROCEDURES

# Appendix C

## Summary Of Near Transfer Procedures

### Sequence of Near Transfer Problems

| | |
|---|---|
| 1. 8 + (-3) = | 6. 4 + (-2) = |
| 2. 5 + (-2) = | 7. 17 + (-13) = |
| 3. 14 + (-5 ) = | 8. 7 + (-4) = |
| 4. 9 + (-6) = | 9. 12 + (-7) = |
| 5. 17 + (-13) = | 10. 16 + (-14) = |

The near transfer task was the second part of the third and last session. The problems were sequenced to vary as their positive addend is less than or greater than ten. The sequence and type of prompts are identical to the training and maintenance sessions.

### Basic Instruction

Giving the student a problem card, the examiner said:

"Can you answer this problem?"

8 + (-3) =

1. If the answer was correct, the next problem was presented.
2. If no or an incorrect answer was given, a sequence of prompts was followed.

### Prompt Sequence

The examiner said:

"I'm going to give a hint. If you can answer with this hint, go ahead. If not, I'll give you another."

1. Demonstrating the concrete integer line, the examiner said:
   "For each positive number we can invent a new number called a negative number. If this number is positive 1, the new number is negative 1. If this number is positive 2, the new number is negative 2".
2. "All the positive numbers are greater than 0 and all the negative numbers are less than 0."
3. "Can you read the problem?" (8 + (-3) )
4. "What are you to do with 8?" (Add -3)

5. "Can you see the number line in your mind?"
6. "Use the number line" (The examiner gives the student the concrete integer line.)
7. "Can you find 8?"
8. "What are you to do with 8?" (Add -3)
9. "To add -3, you move to the left."
10. "You move three spaces to 5."

The card was turned over and the next one was presented. The same procedure was followed for the next problem. After the student solved the first problem without assistance, the examiner told him or her that the session would be finished when she or he solved three problems
in a row without assistance.

Metacognitive Data

After three problems were solved without assistance, the problem cards were shown and the student was asked to explain how she or he solved the problem. To investigate the student's perception of near transfer each was asked:

1. Can you tell me how you solved these problems?
2. Are there any similarities or differences between these problems and the ones you did earlier today?
3. If you wanted to explain how you solved these problems using a rule, what would it be?

# APPENDIX D

# SUMMARY OF
# FAR TRANSFER PROCEDURES

# Appendix D

## Summary Of Far Transfer Procedures

### Sequence of Far Transfer Problems

| | | | |
|---|---|---|---|
| 1. | 3 - (-4) = | 12. | -4 - (-10)= |
| 2. | -5 - (-2) = | 13. | 2 - (-13)= |
| 3. | -2 - (-6) = | 14. | -9 - (-3) = |
| 4. | 7 - (-9) = | 15. | -6 - (-3) = |
| 5. | -9 - (-5) = | 16. | 10 - (-2) = |
| 6. | -4 - (-17)= | 17. | -14 - (-1) = |
| 7. | 11- (-5) = | 18. | -6 - (-2) = |
| 8. | -12- (-5) = | 19. | -13 - (-1) = |
| 9. | -3 - (-9) = | 20. | -16 - (-2) = |
| 10. | 2 - (-11)= | 21. | 6 - (-3) = |
| 11. | -17- (-6) = | 22. | - 7 - (-2) = |

The far transfer task was the third part of the last session. The problems were sequenced to vary the type of problem as there are three types. With the first type, the first addend is positive, and the answer is positive. With the second type, the initial addend is negative, and the answer is negative. With the third type, the initial addend is negative, and the answer is positive.

### Basic Instructions

Giving the student a problem card, the examiner said:

"Can you answer this problem?"

3 - (-4)=

1. If the answer was correct, the next problem was presented.
2. If no or an incorrect answer was given, a sequence of prompts was followed.

### Prompt Sequence

The examiner said:

"I'm going to give a hint. If you can answer with this this hint, go ahead. If not, I'll give you another."

1. Demonstrating, the concrete integer line, the examiner said:
"For each positive number we can invent a new number

called a negative number. If this number is positive 1, the new number is negative 1. If this number is positive 2, the new number is negative 2.

2. "-1 is the inverse of +1. -2 is the inverse of +2".
3. "Can you read the problem?" ( 3 - (-4)=
4. "What are you do with the -4?"
5. "When you subtract the -4, it is the same as adding the inverse of -4".
6. "+4 is the inverse of -4".
7. "How would you read the problem. This is the same as adding the inverse.
8. "Use the number line."
9. " Can you add the inverse of -4 to 3?"
10. " You go to the right, the answer is 7."

The card was turned over and the next one was presented. The same procedure was followed for the next problem. After the student solved the first problem without assistance, the examiner told her or him that the session would be finished when she or he solved three problems in a row without assistance.

Metacognitive Data

After three problems were solved without assistance, the problem cards were shown and each student was asked to explain how she or he solved the problem. In order to investiage the student's perception of far transfer, the following question were asked:

1. Can you tell me how you solved these problems?
2. Are there any similarities or differences between these problems and the ones you solved earlier today?
3. If you wanted to explain how you solved these problems using rule, what would it be?

# APPENDIX E

## THIRD STEP IN DATA ANALYSIS - IDENTIFICATION OF MEANING UNITS

Appendix E

Third Step in Data Analysis - Identification of Meaning Units

Learning

(Student has been given the first problem of the learning task and asked to write the answer)

| Direct Transcript | Number of Identified Meaning Unit |
|---|---|
| [ -5 + (-3) = ] | |
| [Kenneth: . . . (Pauses) I write the answer here? | 20 |
| Examiner: You write the answer here. ] | |
| [K: (Writes 8). | 21 |
| E: Okay, what did you write down for the answer, Kenneth? | |
| K: 8. ] | |
| [E: 8, okay. So what I'm going to do Kenneth is I'm going to help you solve this problem. I'm going to give you a series of hints. First of all, I'll show this (retreiving number line). Do you know what this is called, Kenneth? | 22 |
| K: . . . (Pauses). A number line. | |
| E: That's right. This is called a number line. I'm going to give you hints. If you can solve the problem with the hints I give you then go ahead and solve it. | |
| K: (Nods). | |
| E: If you can't then you can ask me for another hint. | |
| K: (Nods). | |
| E: Okay. Now, I wanted to say to you Kenneth, just to | |

remind you if you wanted to change your answer, just cross it out.

K: (Nods). ]

[E: Okay, right. This is called a number line. For each positive number we can invent a new number called a negative number. If this number is positive 1, the new number is negative 1. If this number is positive 2, the new number is negative 2. 23

K: (Nods).

E: That's my first hint.]

[K: . . . ( Pauses) (Makes unintelligible comment). What are these for? (Points to vocabulary cards; uses chin to indicate direction.) 24

E: No, they're just to help you with the names.]

[K: Do I use this? ( Points to problem cards) 25

E: Have you ever seen a problem like this, Kenneth?

K: (Shakes head).]

[E: If you want another hint you can ask for another hint or you might want to think about that one. 26

K: . . . (Pauses) Can I use the marble? (Points to marble). ]

[E: Well, I have to give you some more hints for you to do that. 27

K: . . . (Looks up and smiles). ]

[E: Do you want another hint? 28

K: (Nods). ]

[E: All the positive numbers are greater than 0 29

and all the negative numbers are less than 0.

K: (Nods).

E: That's that hint.

K: Do I move the marble?

E: Well, (laughs and smiles).

K: (Smiles). ]

[E: I can't let . . . no. I've got to give you some more hints before you move the marble. Do you want another hint? 30

K: (Nods). ]

[E: Can you read the question ? 31

K: 5 plus 3.

E: Okay. This is negative 5 plus

K: Negative 3 . . .

E: Okay. ]

[K: (Unintelligible comment ; pointing to card and indicating direction with chin. ) 32

E: I'm sorry, but I didn't understand you.

K: Do I move the marble to the 3 there?]

[E: Okay. Well, I'll tell you what you can do. What are you to do with -5? 33

K: Yeah.]

[E: Okay. Does that help you at all? (Chin on hand) 34

K: No. (Places chin on hand). (Makes unintelligible

comment).

E: No.

K: (No response). ]

[E: Okay, Do you want another hint? 35

K: (Nods). ]

[E: Okay. You can use the number line. 36

K: Do I move the marble to the -3? (Points with pen) ]

[E: Okay. First of all, can you find the -5? 37

K: (Moves marble to the -5).

E: Okay. That was another hint. ]

[K: (Slight nod). Do I move to the -3? 38

E: Sorry, Do you move to the -3?

K: (Nods).

E: To add -3 you move the left 3 . (Points to number line). ]

[K: (Moves the marble to -8). 39

E: Okay. The answer is

K: Negative 8. ]

[E: The answer is negative 8. Do you want to change your answer then? 40

K: Okay. (Changes answer to -8). ]

[E: Okay. (Places number line beside the table) 41

[ - 8 + (-5) = ]

K: (Writes -13 on problem card)

E: Okay, what is your answer to this one, Kenneth?

K: Negative 13.

E: Negative 13. That's right.

K: (Slight nod). ]

[E: What you are going to do is solve three problems correctly in a row before we finish. 42

K: (Nods).

E: Okay.

[ -11 + (-3) = ]

K: (Quickly writes -14).

E: Okay, what is your answer?

K: Negative 14.

E: Okay.

[ -4 + (-5)= ]

K: (Quickly writes -9).

E: Okay, what's your answer?

K: Negative 9.

# APPENDIX F

## MEANING UNITS
## TRANSFORMED INTO THEMES

# Appendix F

## Meaning Units Transformed into Themes

Learning Task

| Themes | Meaning Units (Appendix E) |
|---|---|
| For the first problem, Kenneth asked if he writes the the answer on the card. | 20 |
| Kenneth answered 8 for the first problem. | 21 |
| Examiner reexplained instructions for interactive diagnosis. | 22 |
| Kenneth nodded after receiving first hint. | 23 |
| Kenneth asked the purpose of the vocabulary cards. | 24 |
| Kenneth asked if he should use the problem cards for problem solving. | 25 |
| Kenneth responded to examiner's prompt that he could have another hint by asking if he could use the marble. | 26 |
| Examiner told Kenneth that he would need another hint in order to use the marble; Kenneth responded by smiling. | 27 |
| Examiner asked Kenneth if he would like another prompt; Kenneth responded by nodding. | 28 |
| After being told that he was given Hint 2, Kenneth asked examiner if he can move the marble. | 29 |
| Examiner stated that more hints are required before he can move the marble; Kenneth nodded agreement that he would like another hint. | 30 |
| For Hint 3, Kenneth read the question as " 5 plus 3"; examiner corrected him by saying "negative 5 plus"; Kenneth completed the question. | 31 |
| Kenneth requested (nonverbally and verbally) to use the marble to solve the problem by asking if he was | 32 |

to move the marble to positive 3.

After Hint 4, Kenneth responded inappropriately by answering "yeah". 33

Examiner requested if that hint aided Kenneth; he replied "No". 34

Examiner asked Kenneth if he requires another hint; he responded nonverbally affirmatively. 35

After Hint 6 which suggests that the student can use the number line, Kenneth asked if he moves the marble to -3. 36

Kenneth moved marble to -5 after Hint 7. Examiner stated that was another hint. 37

Kenneth acknowleged the hint and asked if he "moves to the -3" which resulted in the examiner giving him Hints 9 & 10. 38

Kenneth moved the marble to -8. When asked, Kenneth correctly read the answer. 39

The examiner asked Kenneth if he wished to change his answer on the problem card; Kenneth does. 40

Kenneth answered second problem correctly without any hints. 41

Examiner advised Kenneth of the rules for testing to be finished; Kenneth quickly solved problems 3 and 4 without any assistance. 42

# APPENDIX G

# DESCRIPTION AT SPECIFIC RESEARCH LEVEL

# Appendix G

## Description at Specific Research Level

### Learning Task

For the initial learning problem [ -5+ (-3)= ], Kenneth appeared to ignore the negative signs and wrote the answer of 8. After the hinting procedure was initiated, Kenneth asked several questions concerning what he could use to solve the problem; the vocabulary cards, the problem cards, or the marble. After each hint, Kenneth would reply with a request to use the number line by requesting to use the marble.

Kenneth appeared to confuse the addition of negative numbers with the visual respresentation of the number line by asking after Hint 6 ("Use the number line"), and after Hint 7 ( "Can you find -5?"), if he could "moves to the -3" instead of adding -3. After being given Hints 9 and 10 (to add -3, you move to the left"), Kenneth answered the problem correctly by utilizing the number line. He was able to solve problems 2, 3, and 4 without assistance.

During the prompting, Kenneth tended not to ask for hints, but would agree to the examiner's inquiry asking if he would require another hint.

Kenneth continued to have difficulty understanding questions as demonstrated by his inappropriate response to Hint 4.